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MINISTRY OF AGRICULTURE, EGYPT.

Technical and Scientific Service.
(Plant Protection Section, Mycological Research Division.)
Bulletin No. 74.

The Fusarium Disease of Cotton (Wilt) and its Control.

By
TEWFIK FAHMY, D.I.C., M.S.E.A.C. (Hon. Bot.)
Chief, Mycological Research Division, Ministry of Agriculture.

Submitted for publication on February 9, 1927.

(Recommended for publication by the Publications Committee of the Ministry of Agriculture, which is not, as a body, responsible for the opinions expressed herein.

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MINISTRY OF AGRICULTURE, EGYPT.

THE FUSARIUM DISEASE OF COTTON (WILT) AND ITS CONTROL.

PART I.—INTRODUCTION.

Cotton is certainly the most important crop in this country. The area under cotton in 1925 was 1,924,382 feddans,* of which 1,128,946 feddans, were under Sakel and 795,436 under Ashmouni and other varieties. The Sakel crop was estimated at 3,779,990 qantârs* and the Ashmouni and other varieties at 4,080,939 qantârs, making a total of 7,860,929 qantârs.

The average price of Sakel per qantâr in 1925 was 35·78 dollars and for Ashmouni 25·06 dollars, making a total value of 135,258,000 dollars or L.E. 27,049,000 for the Sakel and 102,268,000 dollars or L.E. 20,453,000 for the Ashmouni and other varieties, and a gross value of 237,526,000 dollars or L.E. 47,502,000 for the whole crop.

So far the varieties most affected by this disease are those producing long staple cotton, of which Sakel is the principal, and the one most grown in the Delta.

It seems to the author that the present and future prosperity of this country depends on the production of long staple cotton. The short staple cotton production in the world is increasing, and sooner or later there may be over-production, which would cause a grave situation if this country should be unable to maintain its long staple varieties.

The frequent occurrence of the *Fusarium* disease in Lower Egypt, where long staple cotton is grown and the increasing damage it has been causing of late years, make this problem of vital importance, and emphasise the necessity of a serious investigation into this matter.

The work was started in 1922. The results obtained, so far, are by no means complete or final; it is hoped, however, by publishing this bulletin to assist materially in clearing up certain points. It is the intention of the author to continue the investigation and to publish progressive reports.

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* *See* Appendix.

History.

Atkinson [2] (1892), described a *Fusarium* found in the vascular tissue of cotton. He succeeded in infecting two plants which were previously attacked by the sore-shin fungus. It was thought that injury to the under-ground parts of the plant might provide a way for the wilt fungus to enter a plant.

In 1899 Erwin F. Smith [24], described what he thought to be the ascogenous stage of the *Fusarium* of cotton wilt. This was said to be a Neocosmospora. He was unable however to infect cotton plants with this fungus and thought that the failure may have resulted from a greater resistance on the part of cotton or from the fact that the natural method of infection has not been discovered. He described his fungus in the following terms :—

" Neocosmospora vasinfecta (Atk.) syn. *Fusarium vasinfectum* Atk. on cotton. Probably also on okra. Parasitism not proved. Genetic connection of various spore forms not proved. Chlamydospores not observed."

Those [25], who followed Smith reported that many wilts were caused by this Neocosmospora, though without real evidence.

In 1900 W. A. Orton [21], published a paper in which he said : " The Wilt disease has been produced in healthy cotton plants by inoculating the soil in which they grew with pure cultures of conidial stages of Neocosmospora vasinfecta (Atk.) Smith. This removes any doubt as to the causal relation of the fungus to the disease which might arise from the failure of the previous inoculation experiments."

In 1902 Victor Mosséri [20], published a series of articles in which he gives the diagnosis of the disease and interesting information as to its occurrence in Egypt.

Delacroix [7] (1902), at the request of Choremi Bénachi and Boyer of Montpellier at the request of Mosseri examined diseased cotton plants and confirmed Mosséri's diagnosis.

Mosséri considered the fungus causing this disease to be Neocosmospora vasinfecta (Atk.) Smith and included a description of the disease on the same lines as those adopted by the American authors. He advocated the use of several agricultural practices and above all the selection of resistant strains as the best mean of controlling the disease.

On the request of the author, Victor Mosséri gives the following historical account on the appearance of this disease in Egypt :—

" Au retour d'une tournée dans un domaine du Prince Ibrahim Pacha Hilmi à Kafr Hammam, près de Zagazig, M. Agathon signale pour la première fois en Egypte (Bourse Egyptienne du 13 juin 1902) une maladie nouvelle des cotonniers ; l'identifiant avec celle qui, 18 ans

auparavant, faisait d'énormes ravages parmi les plantations de coton, dans le vilayet de Balikesser en Turquie, il en souligne les dangers et la gravité. D'après lui il s'agirait d'une maladie cryptogamique due à un Ascomycète.

L'article de M. Agathon émeut le monde agricole d'Egypte jusqu'à influencer la Bourse des cotons, et est le point de départ d'une longue et souvent violente polémique. M. Agathon est accusé notamment d'avoir décrit une maladie déjà connue et étudiée par M. Fletcher.

Celui-ci, mis en cause, publie un rapport (Bourse Egyptienne du 18 juin 1902) duquel il résulte que cette maladie aurait été introduite d'Amérique, 8 ans auparavant, avec des graines de Sea-Island. Il croit pouvoir l'identifier avec le sore-shin des Américains. A son sens, le parasite égyptien est un Ascomycète appartenant probablement au genre Sclerotinia.

Les avis cependant restent partagés et les opinions les plus diverses et les plus fantaisistes sont émises par différents agronomes (Bourse Egyptienne des 16 et 18 juin) : pour les uns, la maladie serait due aux attaques d'insectes ou à des semences avariées (MM. Parachimonas, Lascaris, etc.) ; pour les autres, les attaques cryptogamiques favorisées par des circonstances climatériques seraient seules responsables (M Fletcher).

M. Victor Mosséri cependant, avant même d'entreprendre l'étude de la maladie en pressent la nature exacte (Bourse Egyptienne du 23 juin). Il établit qu'il ne peut être question, comme M. Fletcher le pense, du sore-shin ou seedling-rot, parce qu'un tel parasite ne s'attaque qu'aux semis et aux toutes jeunes plantes, et que la maladie observée à Kafr Hammam sur des plants âgés de 3 mois présente les caractéristiques du *cotton wilt disease*. Cependant il fait justement remarquer qu'en l'absence de tout examen microscopique on peut jusqu'à plus ample information incriminer également un *wilt disease* physiologique, c'est-à-dire un dessèchement des plantes notamment par suite d'une trop forte concentration saline à leur pied.

Mis en possession de plants malades, M. Mosséri en entreprend l'étude et confirme que la maladie observée à Kafr Hammam est un *wilt disease* cryptogamique dont l'agent infectieux est le *Neocosmospora vasinfecta* (voir en particulier l'étude détaillée publiée par le Bulletin de l'Union des Agriculteurs d'Egypte, No. 15, septembre 1902).

Mais, entre temps, des plants malades avaient été envoyés par MM. Chorémi et Bénachi à M. Delacroix de Paris et le diagnostic du savant français venait confirmer en tous points celui, antérieur, de M. Victor Mosséri, à qui revient donc la découverte *cotton wilt disease* (Bourse Egyptienne du 10 juillet). L'un et l'autre incriminaient le *Neocosmospora vasinfecta*.

Cependant M. Mosséri poursuivait l'étude de la maladie et dans un rapport qu'il adressait (Bourse Egyptienne du 12 juillet) à S.A. le Prince Hussein Pacha Kamel, président de la Société d'Agriculture, il en soulignait la nature relativement bénigne en Egypte pour les cotons cultivés alors. Il préconisait déjà comme le meilleur procédé de lutte la sélection naturelle ou artificielle des plants résistant à l'infection en remarquant que les races égyptiennes en faveur à l'époque (Mit-Affifi, Abbassi, Joanovich) s'étaient révélées les plus résistantes en Amérique. Il indiquait également l'utilité d'un assolement où le coton ne revient que tous les 3 ou 4 ans.

M. Mosséri met en garde aussi contre l'abus d'engrais azotés et contre toute pléthore de nourriture.

Il a employé lui-même plus tard la sélection naturelle avec profit, contre le nématode du bananier."

Delacroix and Maublanc [8], called this disease" le chancre du collet du cotonnier." They attributed it to *Neocosmospora vasinfecta*, (Atk.) Smith, the conidial stage of which they considered to be *Fusarium vasinfectum* Atk.

F. Fletcher [13] (1902), in an article on sore-shin and wilt disease gives the following information on the wilt disease :—

"The evidence may be summed up as follows under definite heads :—

(1) The " Wilting " of cotton in Egypt is due, in the greatest number of cases, to the " Sore-shin " fungus (*Pythium*).

(2) Though the disease known as the " Wilt disease " in America is very widely distributed in Egypt and undoubtedly of long standing, it has not before been noticed owing to its very rarely causing " wilting" and death in this country. This is due probably to our cotton trees being more " resistant " to the attacks of the fungus (*Neocosmospora*). The superiority in resistance of Egyptian varieties over American ones has been proved by Orton in the publication mentioned.

In only one case has the writer seen wilting undoubtedly caused by this disease ; this occurred in a Mit-affifi tree 2 metres high, bearing open bolls at the base and flowers at the apex, which had been deprived of all its leaves except a tuft at the top ; on September 2, these remaining green leaves suddenly wilted without any previous change in colour.

(3) Though the Egyptian varieties are much more resistant than the American ones, yet they are not invulnerable by any means and the loss caused by the dwarfing of the plant and the drying of the upper bolls is undoubtedly very great.

The symptoms of the disease being not a sudden wilting of the leaves of the whole plant as is often the case in America, but a gradual fall of the leaves without previous wilting, their colour changing

from normal green to yellow, brown and reddish brown. The lower leaves fall first, the process of defoliation passing along the stem from base to summit until in the course of weeks only a small tuft of green leaves remains at the top of the tree; in many cases the plant is deprived even of these. Only in very few cases does wilting occur in consequence of the attack of this fungus in this country. Whether the plant is thus robbed of all its leaves or still retains a few of the uppermost, the effect differs only in degree, the result in both cases being that if the plant does not die before any of the bolls open, it is only the lower ones that ripen naturally, or at all. The appearance of a plantation in which this has happened is characteristic, areas from a few square metres to several feddans assuming as early as the month of July a brownish appearance, popularly and variously put down to too much or too little water. This effect must not be confused with the brown appearance to be observed later in a plantation when the leaves lose their green colour and fall naturally at the end of the annual vegetative period of the cotton plant. Trees thus deprived of their leaves but not killed outright, often send out new branches from the lower portion of their stem; these abnormal growths are characteristic.

(4) Other symptoms of the disease are :—

A decayed condition of the root tips, these turning a dark brown or olive-brown colour.

Tufts of rootlets on the roots. This abnormal growth is, judging from diagrams (Mr. W. A. Orton [27], U.S. Department of Agriculture) not so well marked as in America.

A few large horizontal branches springing from the base of the stem and very few higher up.

A dwarfed appearance of the whole plant owing to many of its lateral roots being destroyed.

(5) Into the details of artificial cultures and microscopical appearance of diseased tissues it is unnecessary to enter, but it may be stated that the vessels of the wood (xylem) of the diseased parts of roots were found to be blocked by the hyphæ of the fungus bearing spores (Microconidia), exactly as described in the case of the American *Wilt disease.*" *

Fletcher [13] (1902), gives also an extract from a letter received from Dr. W. A. Orton 14/12/1902 who writes that " After an examina-

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* Dr. W. L. Balls, now (1927) Director of the Botanical Section of this Ministry informs the author that he was originally appointed as cryptogamic Botanist to the Khedivial (now Royal) Agricultural Society as the result of this controversy; but that by the time of his arrival in Egypt (December 1904) the general opinion had agreed that diagnosis was incorrect and interest lapsed. No unmistakable cases of Fusarium Disease came under his notice up to 1910 (Text-book of Egyptian Agriculture Vol. II, page 683, Cairo, National Printing Department, 1910).

tion of the material sent, it seems to me there is every probability that you have the same wilt disease of cotton in Egypt that we have in the United States, caused by the fungus *Neocosmospora vasinfecta*. The specimens agree very well with our disease in having the vascular of the stem filled with mycelium of a *Fusarium* and if they had been collected in the United States I would not hesitate to pronounce it the Wilt disease."

Jaczewski [17], [18] (1902–1903), is said to have met with the same fungus on Sesamum orientale in Turkestan.

Zimmerman [27], reported this disease as occurring in German East Africa in 1904.

Fulton [14] (1907), stated that Wilt, black-heart or black-rot is caused by *Neocosmospora vasinfecta* (Atk.) Erw. Sm. Besides cotton, okra is mentioned to be the only other plant susceptible to the attack of this fungus. The disease is given as occurring in North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Arkansas, Taxas, and Louisiana. Under methods of control many recommendations are given and stress is laid on the importance of the selection of resistant varieties.

Evans [11] (1908), gives under " cotton wilt in the central provinces" the following :—

" A field of Bani Cotton, a local variety of rather fine staple was first attacked. This crop was growing on a piece of land in rather high condition, which had been cropped with Juar the year before. The cotton plants were very vigorous and healthy-looking and gave promise of an excellent crop. The first signs of disease were noted at the end of August, when scattered plants were noticed to turn yellow, the leaves to wilt and the whole plant to die and dry up. An attacked plant was often noticed to have completely died within twenty-four hours. On pulling up diseased plants a ring of the bark at the point of the junction of the stem and root was found to have turned brown and to be in a decomposed state, while immediately above this ring the base of the stem was covered with large unhealthy looking swellings which in a later stage are frequently attacked by white ants. These insects being at first suspected of having caused the injury to the plant. Specimens of the diseased plants forwarded to Dr. Butler for examination and have been identified as suffering from cotton wilt disease (*Neocosmospora vasinfecta* Smith). Meanwhile on the other parts of the Farm, Jari and other Indian varieties had been attacked to a less txtent but it was curious to note that American upland varieties which were growing round the edge of the attacked plot were not attacked, nor could a single instance of an American cotton plant suffering from the disease be found."

The same author adds that " on wider inquiries being made cotton was reported to be diseased in several places in the Nagpur District and in the Soaner tract."

According to Duggar [9], the wilt disease of cotton has become prominent during the past fifteen years since the publication of his book (1909). It is said to be one of the most destructive parasitic diseases of cotton and probably distributed throughout the cotton growing States (U.S.A.). The symptoms are given with some detail.

Referring to resistant varieties, Duggar mentions that " Special resistance has been shown by some of the Egyptian cottons although they are not in any case wholly resistant. On the other hand Sea Island cotton is particularly susceptible to this fungus."

Duggar attributes the disease to *Neocosmospora vasinfecta* Smith.

Subsequent work of Higgins [15] (1909), in North Carolina and Butler [4] (1910) in India have thrown some doubt on the parasitism of *Neocosmospora* and on its genetic connection with the wilt producing *Fusaria*.

Higgins [15] concludes that " it seems best to regard *Neocosmospora* as simply an accidental saprophyte, having no relation to the wilt of the cowpea or to the internal fungus, *Fusarium vasinfectum* which is probably the true cause of the wilt."

W. A. Orton [22] (1911), referring to the work of Erwin F. Smith on the wilt disease of cotton, watermelon and cowpea writes :—

" These diseases were fully described by Dr. Erwin F. Smith in 1899. He established the parasitic nature of the watermelon *fusarium* by repeated successful inoculations with pure cultures and suggested the probability that *Neocosmospora* was the ascogenous form basing his opinion on the almost universal occurrence of the perithecia on the roots of the cowpea and watermelon and (less commonly) cotton plants dead from wilt. He showed that a *Fusarium* was the conidial stage of the *Neocosmospora* and developed the ascogenous stage in pure culture of this *Fusarium*. He pointed out in his bulletin that the genetic connection of the parasitic form with *Neocosmospora* had not been fully established by growing the ascospores in cultures originating from internal conidia or by securing infections with cultures originating from ascospores."

W. W. Gilbert [16] (1915), gives interesting information as to the occurrence of the wilt caused by *Fusarium vasinfectum* in the States. He states " wilt occurs almost exclusively on soils of a sandy or sandy-loam nature. In most cases, the lighter the soil the more severe is the wilt. For this reason it is often worst in portions of the field where large quantities of sand have been washed by drainage water. Sandy ridges through the field or high sandy spots are also severely

affected. Rarely has the disease been known to occur on clay soils, and then only when they were adjacent to infected sandy soils."

He adds that root-knot is essentially a disease of light soil and when occurring with wilt the amount of loss is very materially increased. The method of selection of resistant cotton is given with some detail.

Since the work of the last-mentioned author, as far as the writer is aware, nothing of importance has been published, until in 1921 when Ajrekar and Bal [1] published a short paper on this disease.

The outstanding feature of this paper is that the authors isolated two strains of a *Fusarium* sp. capable of producing the wilt disease in the Roseum cotton variety. These two strains, according to the authors, are capable of producing sclerotium-like bodies which differ from one another as to their colour.

In 1924 Daster [6], in a preliminary account seems to doubt that the wilt disease of cotton in India is caused by a species of *Fusarium*, but is inclined to attribute this disease to some other abnormal factors. yet he mentions in his report that Butler in a report, of the Agricultural Research Institute, Pusa, for 1913–1914 (page 55) says: "The cause of the wilt is a species of *Fusarium*; successful inoculations with pure culture of the fungus have been secured."

Dr. W. A. Orton in a letter addressed to Mr. Bailey ex-director of the Botanical Section on the 26/11/23 mentions the following :—

"The older literature is subject to the correction that the perithicial form of Neocosmospora vasinfecta has been shown to be a saprophyte, that the real parasitic *Fusarium vasinfectum* does not have any ascus stage, but has developed as protection for its resting stage the chlamydospore."

Briton-Jones [3] working at Giza (1920–1922) isolated a *Fusarium* sp. from typically diseased cotton plants obtained from Kom Hamada and Damanhour, both in the Behera province, and from similar plants obtained from the Sharqîya province.

The *Fusarium* isolated proved parasitic on Sakel cotton. He described the isolated *Fusarium sp.* after giving its cultural characters on several media in the following words :—

"The above cultural characters of the fungus agree with the descriptions of the conidial stage of *Neocosmospora vasinfecta* (Smith) as described by Erwin Smith and are quite distinct from those described by Butler for his *Fusarium udum*. The latter fungus gives a deep brick-red colour in contact with the substratum, when grown on acid rice and a similar but paler colour on alkaline rice. No suggestion of the colour has been seen in any of the many cultures of the Egyp-

tian *Fusarium* made. According to Butler* the cause of Egyptian Cotton wilt has been identified as *Neocosmospora vasinfecta* (Smith) by Delacroix (sur la Maladie du cottonnier en Egypt. Extrait de l'Agriculture pratique des pays chauds, Vol. II, 1902–1903). The writer has been unable to obtain Delacroix's paper for reference, and has, however, not observed a perithecial stage, and is therefore unable to refer the fungus to any other genus but *Fusarium*. The fungus is therefore considered to be *Fusarium vasinfectum* (Atk.)."

On page 70 Briton-Jones [3] in his Bulletin gives the following foot-note :—

" It is now generally accepted that the genetic relationship between the perithecial stage known as *Neocosmospora vasinfecta* (Smith) and the fungus causing cotton wilt in America has been disproved."

Butler [5] (1926), published an important article on cotton and sesamum wilt. The work was carried out in India in 1912. The *Fusarium* causing cotton wilt in India was isolated from Jari cotton grown at Matargeon Village in the Berars. The writer describes the method he used to isolate the fungus. " Microscopic examination of adjacent sections of the root showed in each case the presence in the vessels of hyphæ resembling those found in the wilt disease of pigeon pea, *Fusarium udum*." He describes the isolated fungus in the following terms : "A *Fusarium* with numerous microconidia and a few macroconidia. Later on, large quantities of chlamydospores developed in the tubes ; in cultures these were collected into stromatic nodular masses."

The isolated fungus proved to be parasitic on Bani cotton, but the writer remarks the following :—

" The percentage of death from wilt in the inoculated pots was low and the incidence of the disease was irregular, some plants escaping altogether while others succumbed, though all must be considered to have been exposed to the same intensity of infection. Nevertheless, those that became infected died in the manner characteristic of the *Fusarium* wilts, the examination of a large number of wilted plants in the field supported this conclusion, and the capricious results of the inoculations would appear to be due to the action of some factor which aids or hinders infection by the fungus. That this factor cannot be a soil one is highly probable from the fact that the same patch of soil was used for each of the two series, while even in the same pot some plants wilted with heavy infection though others survived and were free from internal hyphæ."

The writer then concludes : " The experiments above described do not solve the problem of cotton wilt in Central and Western India."

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* BUTLER, E. J.—" The Wilt Desease of pigoen pea and the parasitism of *Neocosmospora vasinfecta* (Smith)." Mem. Dept. of Agriculture, India, Bot. Ser., Vol. II, No. 9, January 1910.

A little further he adds : "It is believed that they show that the disease is caused by a *Fusarium* which is capable of pathogenic action under certain conditions not yet elucidated and that these conditions are probably not connected with the composition of the soil as has been suggested by J. F. Dastur." *

At the end of the article the writer mentions : " Thus the wilt producing fungi attacking cotton, sesamum, and pigeon pea in India, may in the writer's opinion, best be considered to be strains of *Fusarium vasinfectum* Atkinson, which itself may be merely a strain of one of the earlier described species of the genus."

Distribution.

The disease is prevalent in the fertile parts of the Delta, where Sakel cotton is commonly grown. In upper Egypt, where Ashmouni and Zagora are exclusively grown, it is difficult to detect its presence due to the resistance of these two varieties.

A survey of the occurrence of this disease has been carried out during 1924 and 1925, in Lower and Upper Egypt.

In Lower Egypt the disease was found to be very severe in certain localities and less so in others. In all cases, plants showed the characteristic symptoms and the *Fusarium* isolated from the discoloured roots and stem proved to be parasitic on susceptible varieties at Giza.

In Upper Egypt, so far, no typically diseased plant has been found; a localised peculiar discoloration has, however, been observed within the central cylinder of certain plants of the Ashmouni variety in all the cotton growing localities of Upper Egypt.

This discoloration is of a much deeper colour than the characteristic one in susceptible varieties, and is localised in a way not found in susceptible varieties, Fig. 13. From this discoloured zone a *Fusarium sp.* was isolated, but so far has not proved parasitic on Sakel, or Ashmouni.

This question will be discussed later.

The occurrence of the disease in Upper Egypt is therefore still under investigation.

It is hoped that in due time definite information will be obtained.

Table 1 gives the names of the localities where the disease has been so far observed.

Map 1 shows some of the localities round big centres where the disease occurs. The occurrence of the disease in the other localities in the Delta is under investigation.

Table 2 shows the localities in Upper Egypt where cotton plants, Ashmouni or Zagora, have been found affected with the peculiar discoloration described above.

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* Agric. Journ. of India, vol. XIX, pp. 251–260, 1924.

TABLE 1.—SHOWING THE OCCURRENCE OF THE DISEASE IN LOWER EGYPT.

Province.	District.	Severity.	Province.	District.	Severity.
Gharbîya.	Tanta	Very Severe.	Menûfîya	Ashmoun ...	Very Severe.
	Kafr el Zayat...			Shibin el Kom	
	Dessouk			Tala	
	Zifta	Severe.		Quesna	Severe.
	Santa			Menouf	
	Mahalla el Kobra		Behera ...	Damanhour ...	Very Severe.
	Talkha			Abu Hommos	
	Kafr el Sheikh			Delingat	
	Sherbin	Slight.		Kom Hamada	
	Foa			Tel el Baroud	Severe.
				Shubrakhit ...	
			Sharqîya...	Belbeis	Slight.
Daqahlîya	Simbillawin ...	Very Severe.		Hehya	
	Aga			Fakous	
	Mit Ghamr ...				
	Mansûra	Slight.	Qalyûbîya	Toukh	Slight.
	Faraskour ...	Very Slight.		Qalyûb	Very Slight.

TABLE 2.—SHOWING THE LOCALITIES IN UPPER EGYPT WHERE ASHMOUNI COTTON WAS FOUND DISCOLOURED IN A PART OF ITS CENTRAL CYLINDER.

Province.	District.	Remarks.
Beni Suef	Beni Suef.	All *Fusaria* isolated from the discoloured plants obtained from these localities were found to be non-parasitic on Sakel, Ashmouni and Zagora.
	Beba.	
Fayoum	Fayoum.	
	Itsa.	
Minya	Minya.	
	Fashn.	
	Abu Kirkas.	
Asyût	Mallawi.	
	Dairout.	
	Abnoub.	
	Asyût.	
	Abu Tig.	
Girga	Girga	
	Nag Hamadi.	
	Tahta.	
Qena	Luxor.	
Aswân	Edfu.	
	Kom-Ombo.	

Economic Importance.

The disease attacks, principally, long staple varieties of cotton, as will be shown in the following pages.

It is so severe in some parts of the Delta, that many cultivators in these localities have given up growing Sakel cotton and have substituted for it short staple varieties resistant to this disease.

The conditions in Lower Egypt are most suitable for growing Sakel, which is the most important of the Egyptian long staple cottons. It would be, indeed, a great loss to the country, if as a result of this disease, the growing of this long staple variety had to be abandoned.

Egypt at present produces the bulk of the long staple cotton of the world. Much of the prosperity of the country depends on this fact. Moreover, many countries have since the great war started cotton growing on a large scale. These countries will probably produce cotton of a shorter staple than the Egyptian long staple varieties. It seems, therefore, to the author, that to maintain the present prosperity of this country the production of long staple cotton must be kept up.

To get a clear understanding of the economic importance of this disease, surveys were carried out to estimate the loss.

The localities where the disease occurs were first determined. A list of these is given in table 1. In some of these localities certain villages were selected, and every field under cotton was examined to ascertain if this disease was present, and the percentage of the infected area was calculated. This is shown in table 3.

Table 3.—Showing the Degree of the Attack in certain Localities, 1924.

Province.	District.	Village.	Sakel Cotton.			Other Varieties.		
			Area in feddans.		Percentage Infected.	Area in Feddans.		Percentage infected.
			Total.	Infected.		Total.	Infected.	
Behera... ...	KomHamada	Shubra Ossim ...	83	72	86·7	194	3	1·5
Menûfia ...	Tala	Toukh Dalaka ...	388	12	3·09	58	0	0
Daqahlîya ...	Aga	Miniet Samanoud	696	644	92·5	166	9	5
Gharbîya ...	Tanta	Ragdia ...	88	23	26·1	85	0	0

The degree of infection varied in the different fields from less than one per cent to nearly a hundred per cent.

The method used in calculating the degree of infection was as follows :—

The approximate number of missing plants, and the number of those showing definite signs of the disease (characteristic discoloration of the central cylinder of the root) in different parts of the field, were calculated. In calculating the percentage of diseased plants, the number of actually present plants in neighbouring fields free from the disease was taken as a basis for comparison.

The next step was to find out the percentage of the diseased plants to the total actually present in a field at the maturity of the crop.

This was done in the following manner :—

In 1923 a field of cotton at Toukh Dalaka, Tala (Menûfîya), where the attack, was considered to be of average intensity, was selected. A square area within this field was chosen. This area contained one thousand plants which were still standing at the end of October after the 2nd pick.

The thousand plants were pulled up and their roots examined for discoloration. Part of the root, stem and boll stalk of each individual plant were put in a separate paper bag and brought to the laboratory at Gîza for re-examination.

They were re-examined and isolations made of the roots which showed any trace of discoloration. These results are given in table 4.

TABLE 4.—SHOWING THE SPREAD OF INFECTION IN THE FIELD.

(*a*) Number and percentage of discoloured plants.

Total number of plants left in field.	Number of healthy plants (not discoloured).	Number of diseased plants (discoloured).	Percentage of diseased (discoloured) to total.
1,000	444	556	55·6

(*b*) Discoloured plants giving *Fusarium* culture on isolation from root.

Total number of plants.	Discoloured Total number.	Number of plants giving *Fusarium*.	Percentage of positive isolation	
			To total.	To discolourd plants.
1,000	556	137	14	24·6

From table 4 *a*, and *b*, it can be seen that in a field of average infection, out of the plants left standing at the end of the season, after the 2nd pick, 55·6 per cent were found discoloured. Of these 24·6 or 13·7 per cent of the total (1000) gave positive isolation of the parasite.

It is very difficult to give an accurate estimate of the financial loss caused by this disease. The survey given above is far from being perfect or complete. To carry out an accurate survey in Lower Egypt would require time and a large number of trained staff.

It must be clearly understood that though the following is based on actual observation, it is practically impossible to estimate the financial loss due to this disease, on such a limited number of cases as given here.

The following is put forward as an illustration :—

In the case of Miniet Samanoud (*see* table 3) 696 feddans were under Sakel cotton in 1924. Out of this area 644 feddans showed an average percentage of disease of 25.

This means that 25 per cent of the plants which would have been present or healthy in absence of the disease had died, or were so severely affected by the parasite as to produce a poor yield.

If in the absence of the disease the average yield per feddan is estimated at 4 qantârs, 25 per cent of the plants having suffered from the disease, the reduction of yield at a very reasonable estimate, could be said to be about $\frac{1}{6}$ of the crop or approximately $\frac{2}{3}$ of a qantâr.* At 37·78 dollars per qantâr the loss per feddan would then be 25·18 dollars and the total for the village of Miniet Samanoud $644 \times 25{\cdot}18 =$ 16,215·92 dollars or L.E. 3,243.

Similar cases where the disease is as severe as at Miniet Samanoud are far from being uncommon. In fact the author has observed certain fields where the disease was so severe that only a few plants were left standing in the whole field. All the others had died, the majority at an early age, while many of those left showed the characteristic discoloration of the central cylinder of their roots.

It is hoped that this method of survey will be extended over a very large area in the Delta, with the object of comparing the yield of Sakel in localities where the disease has been observed to be present, to that of other localities free from infection. All conditions being equal it would then be possible to estimate on a larger scale the approximate loss due to the disease.

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* Consideration is taken of the fact that some plants though diseased would have produced few matured bolls.

Description.

The name " Wilt " may suggest, that the wilting of the diseased plant is a necessary symptom. Under Egyptian conditions, such is not the case. Infected plants may appear " externally " healthy and yet on the examination of the roots the characteristic discoloration can be easily observed to be present in the tissue of the central cylinder.

For the sake of clearness the symptoms are divided into two categories :—

(*a*) External.
(*b*) Internal.

By external symptom is meant all apparent characteristic indications of this disease.

By internal symptoms is meant those which can only be detected on examination of the internal tissues of the infected plant, principally those of the root system.

The External Symptoms.

There are two external symptoms, one being characteristic of this disease.

On the Leaves.

The characteristic symptom consists of the appearance of a yellowish network on the leaves. This "mosaic appearance"*, as it is called, starts generally in one corner of the leaf, Fig. 1, and extends until it may cover the whole leaf surface, Fig. 3. It is apparent on both sides of the leaf, but mostly on the upper surface. The affected part of the leaf may or may not dry up ; in the former case, it turns light brown in colour.

If a mosaic portion of a leaf is examined with a hand lens the following is observed :—

Around the smaller veins is an irregular yellowish border about one millimetre or less in width, appearing as if the cause which has induced this mosaic has infiltrated from the veins into the neighbouring tissue and produced this characteristic discoloration, Figs. 2 *a* and 4. In the neighbourhood of the mosaic area, the smaller veins appear very distinct and gradually become less so, the further they are away from the mosaic area, Figs. 2 and 2 *a*. As mentioned above, the whole leaf may or may not be involved. The mosaic symptom is generally more distinct in some parts of the leaf than in others, Figs. 1 and 2.

This symptom appears more frequently in the seedling stage than in the adult plants. It is, in fact, of very frequent occurrence in sus-

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* The term " mosaic appearance" as described above has no relation with what is generally known as Mosaic Disease.

ceptible cotton seedlings grown in infected soil in pots. This frequent occurrence seems to be associated with abundant soil moisture due to the frequent waterings given generally to pot plants. This will be referred to later.

The cotyledon leaves are generally the first to be affected. If the disease is severe, they partially or wholly dry up, and may either drop off or remain attached to the plant.

Sometimes, however, the mosaic symptom appears much later when the plant has produced several leaves, or even when nearly fully grown. The affected leaves are generally the lower ones. They are very few in number and drop off so easily that they generally escape observation. Apart from the mosaic appearance such adult plants may appear normal. Later however, they are frequently recognised by their poor yield and dwarfness.

The examined plants as mentioned in table 4 *a* did not show, when fully grown, any external symptoms by which they could be recognised as diseased apart from the dwarfed state and poor yield of the majority. When, however, the roots were examined 44 per cent were found to be discoloured and of these 24·6 per cent gave pure culture of the Fusarium parasite on isolation.

Although the mosaic has been observed to be a sure sign of the disease, its association with the diseased plant is not constant and for this reason its absence does not indicate freedom from disease.

An experiment was carried out to study the relation between soil moisture and percentage of plants showing the mosaic symptoms.

Sakel cotton was sown in pots filled with infected soil and watered at the periods mentioned below.

Half the number of pots was placed in the field exposed to full sunlight, the other half in partial shade.

Table 5 gives the results.

Table 5.—Showing the Percentage of "Mosaic Appearance" when Seedlings are Watered at Different Periods.

Period of waterings.	In partial shade. Percentage of plants showing mosaic.	In the field. Percentage of plants showing mosaic.
Every day	74·4	73·5
Every 5 days ...	37·5	23·8
Every 10 days...	23·7	None.
Controls (no infection.)	None.	None.

The result shows clearly that soil moisture is an important factor in increasing the number of plants with the mosaic symptoms.

On the Stem.

The other external symptom is the death of the stem, starting at the growing point and proceeding downwards, Figs. 5 and 6. The whole plant may die or may survive by giving rise to new shoots from the lower portion of the stem, Figs. 6, 7, 8 and 9 show different types of this kind of branching.

The dead portion of the stem turns nearly black in colour and on drying becomes somewhat curved, Fig. 5. The newly formed shoots may in turn show signs of disease, such as the mosaic appearance on the leaves or the death of their upper portion. More frequently, however, the recovered plants show marked dwarfness, much basal branching and poor productive capacity.

Fig. 5 shows plants with the mosaic of the leaf and the death of the upper portion of the stem. These plants were grown in artificially infected soil in pots. Fig. 5 *a* shows a cotton plant affected by a kind of physiological wilt. This is given here for the sake of comparison. Figs. 7, 8 and 9 show plants which, after the death of the upper portion of the stem, developed basal shoots which to all appearance look vegetatively healthy.

Infected plants whether they show external symptoms or not, are generally dwarfed. Yet vigorous tall plants, sometimes heavily laden with bolls have been observed to be infected.

The behaviour of the progeny of such plants is under investigation. The author is inclined to believe that they may be hybrids.

THE INTERNAL SYMPTOMS.

The root of a diseased plant which has passed the seedling stage always shows a characteristic discoloration on being cut longitudinally. This discoloured tissue is dark olive green and is arranged in a sort of irregular "bundles of streaks," Fig. 10, extending continuously up the root to the stem. These bundles of streaks, as they may be called, may be limited to certain portions of the central cylinder, Fig. 11, or may be uniformly spread through the whole woody tissue, Fig. 10.

This characteristic discoloration need not be limited to the roots, as mentioned above ; but is generally found in the central cylinder of the stem of diseased plants, extending from the root system upwards. It may reach the growing tips of the branches and even the boll stalk. Its presence in the boll stalk as a possible source of infection of the seed, will be discussed later.

In the infected seedling this discoloration is not so characteristic as in the case of the older plant. It is light brown, sometimes so faint that it is difficult to identify, with certainty, Fig. 12.

The colour of the discoloration met with in adult diseased plants is important. It has been observed to be, in susceptible plants when freshly examined, of an olive green colour as mentioned above and which as the plant loses its succulence takes on a deeper tone, and loses practically all its greenish colour if the plant is left to become entirely desiccated.

In resistant varieties such as the Ashmouni and Zagora a discoloration has been observed in some plants, Fig. 13. This discoloration is very different from that present in susceptible varieties. For convenience, this peculiar discoloration will be referred to as " Upper-Egypt " discoloration, for the reason that it has been mostly observed in Upper Egypt where the Ashmouni and Zagora varieties are grown. This " Upper-Egypt " discoloration is localised in a part of the central cylinder of the root, hypocotyl or lower portion of the stem. It is black in colour or nearly so as shown in Fig. 13. On isolation, these discoloured portions give a Fusarium which up to now in the case of the fungus isolated from the Ashmouni or Zagora cotton plants has not proved parasitic on susceptible varieties, nor on Ashmouni or Zagora. This question will be considered again later in this bulletin.

Besides the discoloration present in the infected plants in Lower Egypt, sometimes a swelling is present in the hypocotyl region where the discoloration occurs. This swelling is slight and may show a depression with a sort of cortical overgrowth round it, Fig. 14. This symptom, like the mosaic, is not always present in diseased plants and therefore its diagnostic value is of secondary importance.

The Causal Organism.

The Parasite within the Host.

When hand sections of the roots of an infected plant are examined microscopically the discoloured tissue is found to contain hyphæ of the parasite within some of the xylem vessels. These hyphæ may be so crowded together as to plug some of these vessels, or may be so sparse that only a few hyphæ can be observed, Figs. 15 and 16.

The hyphæ may be creamy white in colour or of a yellowish tinge, as if externally coated with a pale yellow gum-coloured substance. The walls of the xylem vessels may also be stained a deeper yellow. The same yellowish colouring matter may also fill some of the smaller cells near to the invaded xylem vessels. Other cells may also be filled with a very dark gum-like substance. Certain cells

of the infected plants were also observed to contain globular swellings. The majority of these swellings were found to be tyloses. In some cases they completely filled the cells.

So far, no spores of any kind have been observed within the invaded cells. In a growing plant, the roots of which have not yet undergone any rotting, the parasite seems to limit its invasion to the xylem vessels. If, however, the stem near the hypocotyl of a diseased plant is disinfected externally, so as to kill any saprophyte, and kept under a moist sterile bell-jar at room temperature (25° C.) a *Fusarium* appears on the surface within a week, which proves parasitic on susceptible cotton, Fig. 17.

Under field conditions, this fungus, at any rate in this country, has not been observed growing externally on infected plants while still standing in the field. This is apparently due to the climatic conditions prevalent in this country during the period when the plants are growing.

A hundred adult plants which showed the characteristic discoloration of the central cylinder of their roots were selected at random from an infected patch after the crop had been picked.

Isolations were made from the root, middle part of the stem, tip and boll stalk of each of these hundred plants.

Table 6 gives the result of successful isolations of *Fusarium* fungus from these parts.

The *Fusarium* of a selected number of the different respective isolations was tested and in every case the fungus was found parasitic on Sakel cotton. This result shows that the parasite can invade the tissue of the host, right up to the growing point and boll stalk. The root, and hypocotyl region, however, seem to be the most suitable parts of the host from which to isolate the parasite.

TABLE 6.—SHOWING THE NUMBER OF SUCCESSFUL ISOLATIONS MADE FROM ROOTS, STEMS, TIPS AND BOLL STALKS.

Number of Isolation.	Percentages of successful isolations of *Fusarium*.			
	Root.	Stem.	Tip.	Boll Stalk.
100	69	50	23	9

Isolations were also made from leaves of seedlings showing the mosaic appearance. A *Fusarium* was isolated, which also proved parasitic on Sakel cotton.

Method of Isolation.

The parasite is easily isolated. The following method has so far proved most satisfactory :—

The tap-root of a diseased plant is first washed in running water, being well rubbed with the fingers to rid it of all adhering soil. The upper portion of the tap-root is then cut into short lengths of about 1 to 2 centimetres long, and with clean hands the cortical layers are removed. Each peeled piece is then washed separately in several changes of distilled water, and then seized with sterile forceps and dipped into 2:1000 mercuric bichloride for a few seconds. It is then washed in a tube containing sterile water, dipped into rectified alcohol and flamed and quickly dropped into a tube of a sterile cotton wool medium (M. 1) * or Prune Agar (M. 2) and incubated at 30° C.

Growth appears generally within a week, as white mycelial tufts either from one or both of the cut ends or from the peeled surface (Fig. 18) and consists first of hyphæ with few microconidia, followed by macroconidia and later by chlamydospores. Transfers can be easily obtained from this mycelial growth. If the culture tube is too dry or left for sometime in the incubator, this fluffy growth collapses and forms a sort of adhering white crust on the wood.

Parasitism

In the first part of this work no attempt was made to obtain single spore cultures of the parasite.

The fungus was isolated from the roots of Sakel cotton plants obtained from infected fields in the four provinces of Lower Egypt where the disease is known to cause great havoc.

Similarly, isolations were made from Aṣhmouni cotton obtained from six provinces of Upper Egypt. These Ashmouni cotton plants though not apparently diseased, had the " Upper-Egypt " discoloration referred to above. They all gave a pure culture of *Fusarium* on isolation.

The Method.

From each respective isolation, transfers were made on sterile acid potato plug (M. 3) and incubated at 30° C. for 10 days. The growth of the fungus covered the whole of the potato plug, Fig. 19.

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* *See* Appendix.

An equal number of tubes of cultures of the *Fusarium* isolated from specimens obtained from each respective province, was broken up in a known amount of distilled water in separate beakers. The contents of each beaker were mixed up separately with a known amount of dried Nile mud, which as far as was known had never been used before for cultivation, at any rate in this country. This kind of soil was used in preference to sterilised soil, as sterilisation renders the soil unsuitable for the growth of cotton seedlings. Also, it has been repeatedly observed that dried Nile mud does not contain the parasite.

When the soil was well mixed with the culture suspension, sterilised pots 20 by 24 cm. were filled. An equal number of pots was also filled with uninfected dried Nile mud.

Sakel and Ashmouni cotton were sown separately in an equal number of infected and uninfected pots.

Table 7 gives the results obtained.

TABLE 7.—SHOWING THE PARASITISM OF THE FUSARIUM ISOLATED FROM THE SAKEL AND ASHMOUNI COTTON OBTAINED FROM THE PROVINCES MENTIONED BELOW

Locality from where diseased plants were obtained.		Results of infection.						Remarks.
		Sakel.			Ashmouni.			
Province.	District.	Total.	Healthy.	Diseased.	Total.	Healthy.	Diseased.	
Behera	Delingat	36	0	36	36	36	0	Lower Egypt.
	Kom Hamada ...	36	13	23	36	36	0	
Gharbîya... ...	Kafr el Zayat ...	36	5	31	36	36	0	
	Tanta	36	5	31	36	36	0	
Daqahlîya ...	Mit Ghamr... ...	36	15	21	36	36	0	
	Mansûra	36	8	28	36	36	0	
Minoûfia ...	Tala	36	13	23	36	36	0	
Beni Suef ...	Beni Suef	36	36	0	36	36	0	Upper Egypt.
Fayûm	Fayûm	36	36	0	36	36	0	
Minya	Abu Kirkas ...	36	36	0	36	36	0	
Asyût	Mallawi	36	36	0	36	36	0	
Girga	Girga	36	36	0	36	36	0	
Qena	Luxor	36	36	0	36	36	0	
*Control (no infection) ...		36	36	0	36	36	0	

* The control (no infection) will not be given in the following tables as no disease occurred.

The *Fusarium* parasite was reisolated in every case where infection occurred and proved again parasitic on Sakel cotton.

From the above it can be clearly seen that the fungus is parasitic on Sakel and that Ashmouni is immune to this disease at any rate as far as this test is concerned.

The parasitic capacity of the fungus isolated from the different provinces seems to vary. This question requires further investigation. In fact single spores from each of the above Lower-Egypt provinces are being isolated for comparative tests as to their parasitic capacity and cultural characters.

As to the *Fusaria* isolated from the roots of Ashmouni and Zagora cotton grown in Upper Egypt, they were found to be non parasitic. In 1926 Sakel cotton was grown at Mallawi (Asyût province) and Abu Kirkas (Minya province) where the peculiar "Upper-Egypt" discoloration had been observed during the previous year. At thinning, some seedlings were found discoloured at their central cylinder and a *Fusarium* was isolated. Later when the remaining plants were fully grown, they were pulled up and their roots examined, none gave the typical discoloration. Isolations were made from all roots showing any trace of discoloration and a *Fusarium* was obtained from some of them.

The isolated *Fusaria* were tested, and were found to be non parasitic on Sakel, Ashmouni and Zagora.

It seems then reasonable to conclude that the *Fusarium* or *Fusaria* found within the tissue of cotton grown in Upper Egypt whether this cotton is Ashmouni, Zagora, or Sakel, are of saprophytic nature, and have probably gained entrance through some injury caused during the life-time of the plant.

THE MORPHOLOGICAL AND CULTURAL CHARACTERS OF THE FUNGUS.

Single-spore Isolation.

The fungus was isolated from typically diseased Sakel cotton plants obtained from plot 26 at Gemaiza and from the mycological plot at Giza. Eight isolations were made on cotton wool medium (M. 1) each isolation being from a single plant, three of which were from Gemaiza and five from Gîza. All these isolations gave a pure culture of *Fusarium*. The fungus was transferred on acid potato plug (M. 3).

A week later single spore isolations were made from each of these subcultures which for convenience sake will bear the No. 1 to 8.

The method employed is that of Sherbakoff [23], but slightly modified to suit Egyptian conditions.

This is as follows :—

A spore suspension was made in a tube of sterile water for each of the eight subcultures. Further dilutions using weak Richards' solution (M. 4) were made until when a droplet, about or less than half a millimeter in diameter, was examined microscopically, it contained in the majority of cases one spore but no mycelium. A number (2 to 4) of these droplets was placed on a sterile, large circular cover glass, by means of a flattened platinum needle made into a loop of less than a millimetre in diameter. These droplets were placed at least half a centimeter apart. The cover glass was then inverted and placed on a tubular glass cell previously sterilised, a drop of a sterile water being placed at the bottom of this cell. The cover glass was sealed to this moist chamber by placing a very thin coating of sterile vaseline between it and the tubular glass.

The droplets were then examined microscopically. All those containing a single spore were marked by making a circle round them on the cover slip with a grease pencil, while those containing more than one spore were marked by a cross. The moist chambers were then placed in a Petri-dish containing moist filter paper and incubated at 30° C. The droplets containing one spore were again examined after 6, 12 and 36 hours incubation to ascertain if germinating spores were present. Twenty-four hours later growth was sufficient to permit transfers being made from each droplet, containing originally a single spore. The transfers were made directly on acid potato plug (M. 2).

The method of blotting out droplets containing more than one spore, as suggested by Sherbakoff [23] was found unsuccessful under Egyptian conditions because the droplets being left uncovered during microscopic examination quickly dried. With the method used there was however no danger of the spores from one droplet contaminating another droplet because these droplets were far apart and great care was taken during the transfer.

The following table shows the list of the single spore cultures obtained and their origin.

TABLE 8.—SHOWING THE ORIGIN OF SINGLE SPORE CULTURES OBTAINED.

Origin of plant.	Reference Number of single spore isolation.	REMARKS.
Gemaiza Plot 26. ...	1	Each original isolation was made from one adult plant grown in naturally infected soil.
,, ,, ...	2	
,, ,, ...	3	
Giza Mycological Plot	4	
,, ,,	5	Each original isolation was made from one cotton seedling grown in artificially infected pots.
,, ,,	6	
,, ,,	7	
,, ,,	8	

The Parasitism of the Single Spore Cultures.

The above eight single spore cultures were tested as to their parasitic capacity. The soil and the pots used were previously sterilised and equal amounts of the respective single spore cultures were placed in pots allotted for each single spore culture.

All proved equally parasitic. Single-spore No. 7 was selected for future studies.

THE MORPHOLOGY.

The culture used for this description was a second transfer of single-spore No. 7 mentioned above. The medium used was acid potato plug (M. 3).

The culture developed normally, exhibiting all forms of spores: microconidia, macroconidia and chlamydospores. It was examined after 40 days incubation at 30° C.

Microconidia.—(0–3) septate typically 0 and 1 septate, majority ellipsoidal, sometimes slightly curved, few globose to pear shaped, rarely comma shaped, Figs 33. and 34.

Measurements (average) :—

0– Septate ... ... 5·5 × 3·85μ
1– ,, ... 10·6 × 3·9μ
2– ,, ... 12·1 × 3·9μ
3– ,, ... 15·7 × 4·1μ

Macroconidia. * — (0–5) Septate typically 3 and 4 septate, slightly sickle-shaped to straight, gradually attenuate more towards the apex, pedicellate, Figs. 33 and 34.

Measurements (average) :—

0–	Septate	... ...	rare
1–	„	... ...	„
2–	„	... ...	„
3–	„	... ...	20 × 4μ
4–	„	... ...	28 × 4·2μ
5–	„	... ...	35 × 4·5μ

Chlamydospores.

Subglobose to spherical generally smooth and thick coated. Terminal 0–1 Septate formed on and in mycelium. Intercalary single or in chain rarely in cluster, Fig. 35.

In old cultures and under reduced æration conidial chlamydospores developing mostly in macroconidia, Fig. 36. These may be of the same thickness as the conidia or may be thicker and bulging out. In each case however the spore coat is smooth.

The measurement of the mycelial chlamydospore varies between 5 μ and 15 μ.

For other characteristics *see* page 59.

Microconidia, macroconidia and chlamydospores are colourless with perhaps a very faint bluish hue.

All spores have been found to vary slightly in size and number on different media and at different ages of the culture.

It appears to the author that the taxonomic value of spore measurement is very doubtful.

Sporodochia have not been observed by the writer so far, but Mr. E. W. Mason of the Imperial Bureau of Mycology to whom the writer sent a culture writes the following: " Since the receipt of your last letter (25, 11,24) however, I have examined a tube that I have not opened and found a few sporodochia with macroconidia of the typical size and shape."

The tube in question had not been opened for a year, a condition which may induce the formation of sporodochia. The culture sent to Mr. Mason was not started from a single spore. It was however parasitic and morphologically identical with single-spore culture No. 7.

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* The terms microconidia and macroconidia are applied here as indicated in the article by, H. W. Wollenwebber, C.D., Sherbakoff, O. A., Reinking, Helen Johann and Alice A. Bailey, Fundamentals for taxonomic studies of fusarium Journal of Agricultural Research —Vol. XXX, No. 9, May 1925.

The Mycelium.

The hyphæ are copious, slightly branched, some are very granular, varying greatly in breadth (2·5 μ to 5 μ). Septation varying in size, Figs. 33 and 34. The hyphæ appear colourless under the microscope but in mass when grown on acid potato plug the mycelium is not pure white but has a very faint bluish hue, and is cottony in appearance, Fig. 19.

Anastomosis occurs but is rather rare.

Tufts or balls of loose or compact hyphæ are sometimes formed and frequently on the surface of potato plug medium, there are definite groups of small roundish bodies, Fig. 39.

In a drop of water these small bodies become more or less separated into smaller bodies and appear to the naked eye as fungal bodies, but, when examined microscopically, they are observed under the low power as definite small bodies with few hyphæ growing loosely round them. When stained with iodine solution they show the characteristic starch reaction. Moreover similar bodies without the loose hyphæ have been observed in sterile potato plug medium (M. 3). Therefore they can hardly be considered as characteristic fungal bodies. The author is thus lead to the conclusion that they are simply fragments of the potato which the fungus was able to separate by growing round them, Figs. 37 and 38.

As the culture advances in age and becomes dry, these groups of small bodies take on a yellowish colour and make the media feel gritty to the touch, Fig. 39.

On nutrient liquid medium such as weak Richard's solution, (M. 4) Butler's[4] standard solution + Glucose or saccharose, growth is rapid and there is abundant formation of microconidia by the second day while chlamydospores appear much later. Fig. 20 shows two flasks with the fungus growing on Butler's standard solution + Glucose (1*a*) the other + saccharose (2*a*.)

Spore Germination.

The Microconidia and Macroconidia.

In sterile water at room temperature (25° C.) microconidia and macroconidia germinate producing a thin septate hypha from one or more of their septate portions.

This hypha bears microconidia on short sporophores when the culture is two days old, while chlamydospores are formed three days later. Anastomosis occurs sometimes at about the same period as the chlamydospore formation. The point where the two hyphæ anastomose becomes slightly swollen.

Some chlamydospores germinate readily in water after 24 hours without requiring any resting period, others germinate much later at irregular periods while others do not germinate, at any rate, for the period of the week during which the drop cultures were kept under observation.

Germination is preceded by the chlamydospore becoming slightly swollen. This is followed by the protruding of a germ tube through what appears as a narrow passage. Growth proceeds then in the usual manner, Fig. 35 (10).

The nature of growth of the fungus on different media.

Butler [4], in his memoir : The Wilt disease of pigeon pea and the parasitism of *Neocosmospora vasinfecta* (Smith), gives the following media on which he studied *Fusarium udum* : the pigeon pea wilt fungus.

For comparison the author grew the Egyptian cotton *Fusarium* on some of these media with the results given below.

The Media.

The media consisted of a standard solution to which different ingredients were added as indicated in table 9.

The standard solution was made up as follows :—

Ammonium nitrate	10 grammes.
Potassium phosphate	5 ,,
Magnesium sulphate	2·5 ,,
Distilled water	1,000 c.c.

The fungus was grown on the following media and observations were taken up to 4 weeks, incubation being at 30° C.

Table 9.—Showing the kind of Media and the nature of Growth obtained.

Media.	Growth.	Hyphæ.	Spores.
No. 1*a*. Standard Solution. + 3 % glucose.	Excellent, uniform, from the start, covering all the surface of the medium after 9 days, Fig. 20 (1*a*).	Well developed, similar to that on acid potato plug, but with less branching.	Microconidia abundant, macroconidia rare, chlamydospores intercalary and terminal, well developed.

TABLE 9.—SHOWING THE KIND OF MEDIA AND NATURE OF GROWTH OBTAINED (*contd.*).

Media.	Growth.	Hyphæ.	Spores.
No. 2*a*. Standard Solution. + 3 % Saccharose.	Starts in isolated small islands which as they grow unite until the surface of medium is entirely covered after 17 days, Fig. 20 (2*a*).	Some are granular, as a whole, not so well developed as that on No. 1*a*.	Microconidia numerous, macroconidia rare, chlamydospores intercalary and terminal, both rare and not so well developed as that on 1*a*.
No. 3 *a*. Standard Solution. + 3 % Maltose.	Starts as submerged sparse growth then gradually coming to the surface, covering it, later sinking and becoming somewhat gelatinous.	Similar to that on No. 1*a* but some hyphæ are short segmented and granular, others are swollen at intervals as if attempting to form chlamydospores.	Microconidia abundant, macroconidia very rare, chlamydospores rare, terminal and intercalary, mostly 0 Septate.
No. 4 *b*. Standard Solution. + 5 % Glycerine.	Scanty submerged, some parallel strands on glass, as a whole very poor.	Very thin and filamentous, few are attempting chlamydospore formation, anastomosis frequent.	Microconidia few at start, later increase greatly in number, macroconidia very rare and faint scarlet in colour, mostly intercalary.
No. 5 *c*. Standard Solution + 5 % Gum acacia.	Scanty submerged filling all medium, no surface growth, few islands appearing later on surface.	Thin, attempting chlamydospore formation, as a whole very poor.	Microconidia abundant macroconidia very rare chlamydospores rare.
No. 6 *d*. Standard Solution + 1 % Peptone.	Starts in small islands which later become submerged.	Similar to that on No. 5 *c*.	Microconidia and macroconidia few, poorly developed, chlamydospores also poorly developed and rare.
No. 7 *d* Standard Solution + 1 % Asparagin.	Starts as submerged growth but later few islands are formed which afterwards sink.	Similar to that on No, 5 *c*.	Microconidia many, some are large, macroconidia not observed, chlamydospores are rare and poorly developed.

TABLE 9.—SHOWITG THE KIND OF MEDIA AND NATURE OF GROWTH OBTAINED (*contd.*).

Media.	Growth.	Hyphæ.	Spore.
No. 8 *e* Standard Solution + 1·5 % Citric acid.	Starts as isolated islands which later sink, others reappear on the surface to sink again, as a whole, growth is moderate.	Some are well developed.	Microconidia abundant, macroconidia many, chlamydospores numerous, terminal and intercalary, many large in size and well developed.
No. 9 *e* Standard Solution + 1 % Sodium Carbonate.	Poor growth and submerged.	Poorly developed, few slightly swollen attempting chlamydospore formation.	Microconidia few, macroconidia not observed, chlamydospores very few and poorly developed.
No. 10 *g* Standard Solution + 5 % Absolute Alcohol.	Starts as submerged growth, later few islands appear which afterwards sink.	As a whole poorly developed.	Microconidia present, macroconidia not observed, chlamydospores many but as a whole poorly developed.

CONCLUSION.

The best growth obtained is that on the standard solution + 3 per cent glucose. The next best is that on + 3 per cent saccharose. Apparently the fungus is better able to utilise the glucose than the saccharose. The medium containing the maltose is less suitable than that containing the saccharose, but affords better food for the fungus than the other several media.

The media containing 1·5 per cent citric acid gives the fourth best growth and is interesting from the point of chlamydospore fornation. In this case the chlamydospores are numerous and well developed contrary to what occurs on other media, especially on that containing sodium carbonate.

The fungus on unsuitable media starts its growth as submerged thin hyphæ; sometime after this stage of submerged growth a few islands (small independent centers of surface growth) start to appear, and later sink. On some media, however, the fungus gives rise to a poorly developed mycelial growth on the surface of the glass.

The identification of the Fungus.

The fungus causing this disease in Egypt is, as shown in the above description, a *Fusarium sp.* It has no connection with an ascomycete.

The identification of this *Fusarium* is discussed at some length in part II, where a comparison between the Egyptian, Indian and *Fusarium vasinfectum* is given.

THE RELATION BETWEEN HOST AND PARASITE.

The excretory substance of the Fungus.

As mentioned above, an infected plant shows the presence of the hyphæ of the parasite within the xylem vessels. These hyphæ may partially or wholly plug some of these vessels. A gum-like substance is also observed within some of the cells. The amount of either hyphæ or gum, however, is hardly enough to cause the plugging of all the conducting vessels and to prevent the ascent of sap so as to cause wilting.

The author [12], in a previous paper studied the production by *Fusarium solani* (Mart). Sacc. of a toxic excretory substance capable of causing wilting in plants.

The excretory substance of *Fusarium solani* was found capable of causing broad beans to wilt, when placed in the filtrate of a liquid culture medium.

The wilting occurred after a period varying from 2 to 24 hours, according to the age of the culture. In the case of the boiled filtrate it took a little longer for the wilting to occur.

A similar investigation was carried out in the case of the *Fusarium sp.* causing the disease under consideration.

The fungus was grown on dilute Richard's solution (M. 4) for 14, 42 and 63 days at 30° C. The filtrate after each respective period of growth was titrated as well as the sterile Richard's solution for comparison using as indicator phenolphthalein. The results are given in Fuller's scale.* In each respective case the same quantity of medium was used and inoculated with the fungus. After the required period of incubation the liquid remaining in the culture was filtered. The filtrate, which was light to dark amber in colour according to the age of the culture, was then divided into two equal portions, one of which was boiled and the other left unboiled. Sakel and Ashmouni cotton

* The plus and minus on Fuller's scale denote respectively acidity and alkalinity of the substance. The —10 for example means that exactly 10 cubic centimetres of normal acid N/1 must be added to a litre of the substance to render it exactly neutral to the indicator used, correspondingly +3·8 means that the substance is acid and that 3·8 cubic centimetres of normal alkali N/1 would be needed to be added to the litre to bring it to the neutral point.

seedlings 15 days old, after being first washed in water to free them from mud adhering to their roots, were placed, some in test tubes filled with the boiled and others with the unboiled filtrate. In every case an average of six tubes of each was used. One cotton seedling was placed in each tube. Other test tubes were also similarly filled with sterile weak Richard's solution (M. 4) and others with distilled water and a cotton seedling placed in each. All those test tubes with the cotton seedlings placed in them, were put in stands next to a north window in full diffused light. The average room temperature during the whole period of this investigation was about 25° C.

Table 10 shows the results, and figs. 21 and 22 show Sakel and Ashmouni cotton seedlings, after complete wilting has occurred in those placed in the boiled and unboiled filtrate. The unaffected seedlings in the sterile Richard's solution and distilled water are also shown.

The seedlings in the distilled water remained apparently unaffected for 4 days, while those in the Richard's solution remained normal for 7 days, after which the Richard solution having become polluted, the growth of saprophytes caused the seedlings to wilt and die.

TABLE 10.—SHOWING THE WILTING POWER OF THE FILTRATE AND ITS DEGREE OF ALKALINITY.

Age of culture. (Days).	Variety of Cotton.	Minutes required for the cotton seedlings to :—				Titration (Fuller's scale).		
		Droop *		Wilt *				
		Unboiled.	Boiled.	Unboiled.	Boiled.	Unboiled.	Boiled.	Richard's Solution (M. 4).
14	Sakel... ...	330	330	1,170	1,170	+ 3·8	+ 3·8	+ 9·8
	Ashmouni...	330	330	1,170	1,170			
42	Sakel... ...	120	150	150	150	— 10	— 10	+ 9·8
	Ashmouni...	120	150	150	150			
63	Sakel... ...	30	30	135	135	— 12	— 12	+ 9·8
	Ashmouni...	30	30	135	135			

* By drooping is meant the state when the cotyledon leaves of the cotton seedling lose urgidity and droop. By wilting is meant the entire collapse of the leaves.

From table 10 the following are apparent :—

(1) The time required for plants to droop or wilt decreases with the increase of age of the culture from which the filtrate is obtained.

(2) The fungus causes the medium to become alkaline. The degree of this alkalinity increases with the age of the culture as follows :

Alkalinity due to 14 days growth ... ... 9·8—3·8 or 6 (Fuller's scale).

Alkalinity due to 42 days growth ... ... 9·8+10 or 19·8 (Fuller's scale).

Alkalinity due to 63 days growth ... ... 9·8+12 or 21·8 (Fullers' scale).

The above No. 1 and 2 are shown graphically in graph No. 1 and 2 for Sakel (unboiled filtrate.)

(3) *The Fusarium sp.* causing this cotton disease excretes a toxic substance capable of causing wilting in cotton seedlings.

The Temperature Relation.

The optimum temperature for the growth of the parasite in pure culture was found to be between 30 and 35° C. on acid potato plug, (M. 3).

The progress of the parasite within the host under different temperatures was also studied.

Thirty pots, receiving equal amounts of parasitic culture, were repeatedly sown, each with 10 seeds of Sakel cotton at the date mentioned in table 11.

The average period required for the first appearance of the mosaic symptom after each sowing was noted, Records of the maximum and minimum temperatures were kept during the whole period of the investigation and the average temperature for each period, was calculated.

From table 11 it is clear that the period required for the appearance of the mosaic symptoms varies directly with the average temperature during the growth of the infected plant.

TABLE 11.—SHOWING THE RELATION BETWEEN TEMPERATURE AND TIME REQUIRED FOR APPEARANCE OF MOSAIC SYMPTOMS.

1st Sowing on 10–2–1924.*				2nd Sowing on 18–4–1924.*				3rd Sowing on 18–6–1924.*				4th Sowing on 23–7–1924.*				5th Sowing on 28–8–1924.*				6th Sowing on 20–10–1924.*			
Temperature (Centigrades).			Days.	Temperature (Centigrades).			Days.	Temperature (Centigrades).			Days.	Temperature (Centigrades).			Days.	Temperature (Centigrades).			Days.	Temperature (Centigrades).			Days.
Average Maximum.	Average Minimum.	Mean of Day.	Average for Mosaic to appear.	Average Maximum.	Average Minimum.	Mean of Day.	Average for Mosaic to appear.	Average Maximum.	Average Minimum.	Mean of Day.	Average for Mosaic to appear.	Average Maximum.	Average Minimum.	Mean of Day.	Average for Mosaic to appear.	Average Maximum.	Average Minimum.	Mean of Day.	Average for Mosaic to appear.	Average Maximum.	Average Minimum.	Mean of Day.	Average for Mosaic to appear.
25·5	8·5	15·9	58	32·2	15·6	23·7	14	35	18·2	26·1	14	35·6	18·2	26·9	12	35·5	18·7	25	14	29·7	13·7	20·6	22

Mean Temperature of Day = Average of Temperature taken at the following hours of the Day :—

$$= \frac{+ \text{8th} + \text{14th} + \text{20th} + \text{Minimum.}}{4}$$

* This expression means day, month and year respectively.

SUSCEPTIBILITY OF COTTON VARIETIES.
(Egyptian Varieties).

From preliminary tests and observations, the infective capacity of the soil was found to vary. Certain soils seem to suit the parasite more than others.

For this reason, it was thought best to use for the susceptibility test soil from a known infected field.

The soil used was obtained from plot No. 26 at Gemeiza farm. This plot was one of the rotation chequer plots and had been grown with Sakel cotton for two successive years. The plants were observed to have been badly infected, during the second year.

The cotton varieties required to be tested were grown in bottomless pots, fig. 45, filled with soil, and buried in the field as shown in fig. 46.

To increase the infective capacity of this soil the contents of 200 culture tubes (18 cm. × 18 mm.) of the parasite on acid potato plug (M. 3) were mixed with each cubic metre of this soil.

During the cotton season, March to October, four sowings were done in the same pots, *i.e.*, in March, May, July, and September. Table 12 gives the average percentage of the susceptibility of each variety grown.

TABLE 12.—SHOWING THE SUSCEPTIBILITY OF THE COMMON EGYPTIAN VARIETIES.

Variety.	Number of plants.			Per cent of Disease.	Variety.	Number of plants.			Per cent of Disease.
	Total.	Healthy.	Diseased.			Total.	Healthy.	Diseased.	
Sakellaridis* ...	88	3	85	96	Casuli	131	103	28	21
Garofalou ...	80	6	74	92	Afifi	44	35	9	20
310	189	20	137	72	Toudri	282	236	46	17
Assili	244	111	133	54	Pilion	307	266	41	13
Nahda	60	30	30	50	Fathi	194	181	13	6
Nubari	136	104	42	30	Ashmouni ...	489	489	0	0
Abbassi	87	54	23	26	Zagora	259	259	0	0

From table 12 it is possible to see that the different varieties of Egyptian cotton vary in their susceptibility to this disease. Sakel, Garofalou and 310 for example, are most susceptible while Zagora and Ashmouni can be considered immune.

The estimation of susceptibility was calculated on the basis of the number of plants which were found typically discoloured in

* "Sakellaridis" is the full name of the abreviated word "Sakel."

the central cylinder of the roots when the plants were two months old, plus the number of plants which had died at an early age through the disease, all of which gave a *Fusarium* on isolation.

Susceptible Age.

It was observed that the susceptible varieties namely Sakel, Garofalou and 310, become more susceptible as the season advanced. The plants which came up in March lingered for a longer time before dying than those which were sown in May and July. As a matter of fact the majority of the seedlings of May and July died 10 to 15 days after appearing on the surface of the soil. Some showed the mosaic symptoms, others wilted without showing signs of the mosaic. All, however, showed the discoloration in the central cylinder of the roots, from which the fungus was easily isolated.

The wilted plants of the susceptible varieties sown in May and July, showed a distinct brick-coloured zone at the hypocotyl somewhat similar to that caused by sore-shin. The seedling was girdled at that part, thus causing the plant to collapse and gradually dry up. This brick-coloured zone at the hypocotyl was found to be due to the early death of the cambium layer through the injury caused by the *Fusarium* parasite which by then had invaded the whole plant from the root to the cotyledon leaves.

The above described summer symptom, as it occurs in the very susceptible varieties, can hardly be considered typical of this disease, because of the fact that cotton is normally sown in March to April when the temperature is not so favourable for the great activity of the *Fusarium* fungus to cause the above described lesion. It is possible, however, that under field conditions late resown seedlings may exhibit these symptoms.

In the case of the less susceptible varieties the number of seedlings that die at an early age is small. In fact many seedlings show no external symptoms of the disease and yet when pulled up they are found on examination typically discoloured in the central cylinder of their roots.

Though in the case of the very susceptible varieties under severe infection the seedling seems to be the most susceptible age; adult plants are also liable to infection. To test this, the following experiment was carried out.

Briton-Jones[3] working at Giza during 1920–1922 showed that Sakel cotton plants are liable to become infected when a parastic culture is added to tubs, up to six weeks after sowing.

The author continued this test and found that it is possible to produce infection when a parasitic culture is added to healthy Sakel plants grown in large boxes $60 \times 60 \times 80$ cm. up to 126 days after sowing.

In 1925 adult Sakel plants grown in similar boxes received parasitic cultures a year after sowing.

The plants were pulled up six months later, some of their roots were found typically discoloured.

From the above it can be seen that infection is possible at any time during the life of a susceptible cotton plant. The seedling stage is, however, the period when injury is most fatal.

Mosseri [20] suggested that possibly Okra (Hibiscus esculentus) is liable to become attacked by this fungus. The author grew the following plants in soil heavily infected with the cotton *Fusarium* parasite but with negative result.

The plants were :—

Hibiscus esculentus, H. praecose, H. cannabinus, H. mutabilis, Malva parviflora, Althaea rosea, Abutilon sp., Cucurbita pepo, Cucumis Melo, C. sativus, Citrullus vulgaris, Solanum melongena, S. Lycopersicum, Cajanus indicus.

There is no doubt that the Egyptian *Fusarium* parasite of cotton is specialised in its parasitism not only for cotton but for certain strains of cotton.

The mode of Infection.

Natural Infection.

The actual mode of natural infection has not been studied.

Table 13 shows that the incubation period varies directly with the atmospheric temperature during the growth of the plant in infected soil. From the same table it can be seen that the optimum average field temperature lies somewhere about 26·9° C, when 12 days are required for the mosaic symptom to appear on the cotyledon leaves of a Sakel seedling. At this temperature, the seed requires about 48 hours to germinate. If for the sake of discussion it is supposed that the radicle of the seed germinating at this temperature in infected soil comes directly in contact with growing hyphæ of the parasite, it would then take about 10 days for the parasite to infect and cause the characteristic mosaic symptom.

It is interesting to add that Mosseri [20] stated that the incubation period is said to be from 40 to 50 days depending on the progress of the fungus within the tissue.

From table 11 different incubation periods could be calculated for the different temperatures.

Table 13 shows the variation of the possible periods of incubation at different temperatures. The approximate period for the germination of the seed at different temperatures is also given.

The incubation period is obtained by subtracting from the number of days required for the mosaic symptom to appear after sowing, the approximate period required for germination under the different temperatures.

This is shown in graph No. III.

Table 13.—Showing the possible Variation of the Incubation Periods at different Temperatures :—

Average temperature °C.	Approximate period of germination (in days).	Incubation period (in days).
15·9	5	53
20·6	3	19
23·7	3	12
26	2	12
26·1	2	12
26·9	2	10

Wound Infection.

An experiment was carried out to find whether the parasite can develop, if injected into the tissue of the stem of a healthy cotton plant growing in clean soil.

The follwoing varieties of cotton, Sakel 310, Garofalou, Casuli, Assili, Nubari, Pilion, Ashmouni, Zagora and Red leaf were grown in plats, the soil of which was known to be free from the parasite. When the cotton plants were three months old, they were inoculated in the following manner.

At a height of 15 centimetres from the ground, the stem was first washed with distilled water, then gently rubbed with a piece of cotton wool soaked in rectified alcohol and quickly wiped off with dry sterile cotton wool.

About half a cubic centimetre or less of a spore-suspension of the parsite was injected about 2 to 3 millimetres deep into the stem by means of a sterilised hypodermic syringe. Checks were made, by injecting into the respective varieties sterile water. The wounds were left uncovered.

Three months after the inoculation, when the plants were nearly mature, they were uprooted and taken to the laboratory for examination.

In the susceptible varieties, principally Sakel, Garofalou and 310, most of the inoculated plants showed the formation of a distinct swelling at the inoculated part. This swelling was less apparent in

the less susceptible varieties, while in the resistant varieties such as Red Leaf and Ashmouni there was no swelling or practically none.

In the susceptible varieties, there was in the prominent swelling a distinct cavity in the place where the hypodermic needle had punctured the stem, Figs. 24 and 25, while in the resistant varieties a distinct scar was visible, but no cavity was formed, Fig. 23.

It is worth mentioning here that a similar cavity to that described above, occurs at the hypocotyl region in some plants grown in infected fields, as shown in Fig. 14.

When the inoculated stems of the susceptible varieties were slit, a limited area in the tissue of the swelling was found to be deeply discoloured, Fig. 25. This discoloration, which was black or nearly so, occupied the central portion of the tissue of the swelling. From this deeply discoloured portion streaks of characteristically discoloured tissue extended into the stem mostly upwards, Fig. 25. This typical streaky discoloration was most prominent in the susceptible varieties and hardly present in the resistant ones, Fig. 23. From all the discoloured area whether characteristic or not, or from susceptible or resistant plants the fungus was reisolated, and proved again parasitic on Sakel cotton.

Fig. 23 shows stems of resistant cotton plants (Red Leaf and Ashmouni). The central discoloration is very small in comparison with that of a susceptible variety as Sakel, as shown in fig. 25.

A few words are necessary here as to the formation of the swelling described above. The " swelling " seems to be a natural reaction of the host in a part which has been greatly irritated by the presence of the parasite. In the case of the wound infection the swelling occurs at the infected portion. In fig. 25 the wound produced by the puncture of the needle can be seen at the top right hand side of the deeply discoloured portion.

Under natural infection this swelling at the hypocotyl region is not of frequent occurrence, fig. 14. The formation of the swelling is probably due to the injury caused by the parasite to the host in the seedling stage. This question is under investigation and will be discussed later in connection with the selection of resistant plants.

The cause of the formation of the cavity at the swollen region is also worth mentioning. The cavity seems to be formed through the early destruction of the cambium tissue by the parasite. Once the cambium layers are injured they cease to grow, or grow imperfectly, while the tissue adjacent to this limited injured cambium layers continues its growth and as a consequence of this, the cavity is formed.

The results of the wound infection experiment are interesting, because of the fact that some varieties which normally show resistance become locally infected when a spore suspension of the parasite is injected within the tissue.

So far, only one case has been observed, of Sakel cotton becoming infected with Heterodera radicicola. This cotton was grown by the Physiological Division of this Ministry, to study root development in a mixture of soil and sand in a field at Giza. Fig. 26 shows an infected plant. The nematode galls though small are quite visible. To the left of this plant a healthy plant is shown for comparison. Fig. 27 shows an enlarged photograph of an infected root of the same plant. The attack, by H. radicicola is slight as compared with that shown by Lewis [19]. If, however, the attack by Heterodera radicicola on cotton was prevalent in Egypt, in soil infected by the *Fusarium* parasite, the *Fusarium* disease might become much more severe than it actually is.

It has been suggested by Fulton [14] that infection by nematode increases the severity of the Wilt disease.

It is also possible that had the nematode attack on cotton existed in this country, the *Fusarium* resistant varieties of cotton might have become locally infected by the fungus through the wound caused by the nematode parasite.

So far, in this country, little is known about the attack of Heterodera radicicola on cotton and no information is at hand at present as to the resistance of the Egyptian cotton varieties to the root-knot disease.

It has been observed, however, that hosts susceptible to the root-knot disease growing in the same field as cotton, sometimes become badly infected by Heterodera radicicola. This is particularly noticed with Okra (Hibiscus esculentus) and Deccan hemp (H. cannabinus), while the cotton plants growing next to these plants remained healthy. This observation though by no means final suggests that Egyptian cotton varieties may be resistant to the nematode attack.

It is hoped to give attention to this question in the future.

THE RELATION BETWEEN THE PARASITE AND THE SOIL.

The Field.

The parasite is capable of persisting in the soil for many years. The disease becomes manifest every time a susceptible variety is grown. It appears in patches within the infected field, at least during the first few years after it is observed. With time, as the field is sown repeatedly with susceptible varieties, the patches where the disease was first observed increase in area until finally the whole field becomes involved.

The cause of the increase in area of the infective patch is apparently due to the spread of the parasite from the infected area into the neighbouring soil, principally, through the growth of infected roots. These infected roots, as they grow into the soil carry within them the parasite which becomes liberated through their rotting, thus spreading infection into a soil which was originally free from the disease. The plough and other cultural implements may also carry with them fragments of infected roots and infected soil to the neighbouring clean soil. In this way they introduce infection into the clean parts of the field. The first suggestion seems to the author the commoner cause of the spread of infection from the infected patches. Irrigation water undoubtedly also assists in disseminating the parasite in the soil.

There is a common practice in some provinces of skimming off the surface soil of arable fields and using it as litter. This practice is done in the most fertile parts of the Delta where this disease is often prevalent. The soil to be used as litter, which may contain the *Fusarium* parasite, is placed under the animals in the stables. There, it receives organic matter in the form of excrements. As the organic matter in this mass undergoes decomposition, the temperature increases, and in presence of moisture which is generally abundant the *Fusarium* fungus grows saprophitically and infective matter increases. The mixture of dung and soil is taken to the field and used as manure. Infection in this way spreads until finally the whole area of the farm becomes infected.

Experiments are being carried out to find the length of time the parasite can persist in this kind of manure.

An experiment was carried out to test if this disease is seed borne.

Elliot [10] (1923), in a paper described a method by which he was able to isolate the parasite from seed of infected cotton plants.

The seed was delinted with concentrated sulphuric acid and germinated under asceptic conditions. He was able to isolate a *Fusarium* which proved parasitic on cotton and hence concluded that the parasite can be borne within the seed.

In 1924 and 1925 thirty-three single plants which showed typical symptoms of the disease were picked separately. The seed-cotton of every plant was divided into two lots. One lot was ginned in the ordinary way, by means of a hand gin, the other lot was first delinted by hand to remove the greater bulk of the lint, then put in concentrated sulphuric acid until the remainder of the lint was removed. The seed was then washed in water and placed again for five minutes in concentrated sulphuric acid, washed in sterile water and disinfected with 1 : 1000 mercuric bichloride for two minutes, then washed again in sterile water. Some of this treated seed was germinated in sterilised Petri dishes, the other lot was sown in dried Nile mud in pots.

The majority of the seed in the Petri dishes germinated but gave no *Fusarium* nor any sign of disease.

Together with the pots sown with surface sterilised seed, other pots were sown with the lot of untreated seed mentioned above.

All pots were placed on a wooden stool each standing in a basin of water to prevent ants, etc., from invading these pots and possibly carrying infection with them. When the plants were about six weeks they were thinned to two and the thinned plants examined, but no trace of any discoloration was observed and attempts to isolate the parasite from these seedlings failed.

The plants left in the pots were allowed to grow until maturity. No trace of disease was observed during the whole period of growth.

Of the 264 adult plants grown, only 5 plants were found slightly but not typically discoloured, and on isolation the discoloured tissue did not give any growth.

So far, under Egyptian conditions attempts to isolate the parasite or to grow diseased plants from seeds obtained from infected plants have up to now failed.

The possibility of this disease being seed borne will be reinvestigated on a much larger scale during the coming year and the results will be published later.

The Soil.

During the survey carried out to study the distribution of the disease, it was observed that the disease is prevalent in some localities more than in others. These localities are in the most fertile zones of the Delta. Map No. 1 gives the distribution of the disease round some big centres. So far no disease has been found in poor soil, where sodium chloride is present in small amounts, although not enough to prevent the cotton plant growing.

The soil of infected fields as found in the Delta, is generally heavier and darker in colour than that of Giza, where the disease is known to be entirely absent.

It is hoped to study the physical and chemical properties of the soils of infected fields in the different localities of the Delta as compared with those of non-infected fields of the same and other localities. Special attention will be given to hydrogen-ion concentration of these different soils.

The Infective Capacity of the Soil.

It has been repeatedly observed that the infective capacity of the soil varies within the same field. As mentioned above the disease appears, in the majority of cases, in patches within the field. Within these patches the cotton plants die at an early age. In the immediate area surrounding these patches, plants of the same susceptible variety

as is grown within the patches, show no definite apparent signs of the disease, yet when pulled out and their roots are slit the characteristic discoloration is found present in the majority. In fact the disease in this manner is sometimes detected as present some distance from the infective patches.

Again, some fields grown with susceptible varieties of cotton produce plants which appear at first sight as healthy, yet when their roots are examined many are found to be typically discoloured and the parasite can be easily isolated from them.

The different degrees of infective capacity of the soil seem to the author to be due to the amount of infecting matter which accumulates in the soil year after year. The soil becomes so charged with infecting matter that susceptible cotton would, if grown, die at any early age due to the intensity of infection.

To test the above the following experiments were carried out :—

(1) The infective capacity of soil obtained from an infected field was compared with that of the same soil to which a known amount of parasitic culture was added.

(2) The infective capacity of Nile mud to which different amounts of parasitic culture were added was tested.

In the first case, a quantity of soil from plot 26 at Gemaiza was divided into two equal lots *a*, and *b*.

Lot *a* did not receive any parasitic culture, while lot *b* received the contents of 200 culture tubes (18 cm. $\times$ 18 mm.) per cubic meter of soil.

The results are shown in table 14.

TABLE 14.—SHOWING THE COMPARATIVE INFECTIVE CAPACITY OF SOIL.

Variety of Cotton.	Lot *A*. Gemaiza soil only.				Lot *B*. Gemaiza soil + culture.			
	Total.	Healthy.	Diseased.	Per cent. approximate.	Total.	Healthy.	Diseased.	Per cent. approximate.
Garofalou	99	87	12	12	69	14	55	80
Sakellaridis	76	55	21	28	99	42	57	58
310	66	56	10	15	55	20	35	64
Fathi	53	50	3	6	65	57	8	12
White Joannovitch	93	92	1	1	72	65	7	10
Casuli	95	91	4	4	61	46	15	25
Assili	89	87	2	2	74	70	4	5
Dom. Joannovitch...	88	88	0	0	99	96	3	3
Nubari	78	77	1	1	73	67	6	8
Pilion	109	106	3	3	99	92	7	7
Toudri	77	76	1	1	82	77	5	6
Ashmouni	107	105	0	0	90	90	0	0
Zagora	120	120	0	0	102	102	0	0

The result given in table 14 shows that infection increases with the addition of culture. The infective capacity of the soil seems to be directly correlated with the amount of infecting matter present. It seems to the author that the increase in the degree of infection under natural conditions in the field is due to the same cause. The infective matter increases and accumulates as long as susceptible varieties are grown. Soil conditions may also be more suitable for the growth and spread of the fungus within certain areas (patches) in the field. These soil conditions may act directly and beneficially on the fungus so as to increase its growth or they may act indirectly and detrimentally on the plant, weakening its constitution and making it fall more easily a victim to the parasite present in the soil.

It is possible also that infection as a whole may be intensified through the impoverishment of certain plant constituents, in absence of which the plant loses some of its vital capacities and becomes an easy prey to the parasite. It is possible also that these constituents, though present in some form may have become unavailable for the plant.

In connection with the above, an experiment was carried out to test the effect of the application of sulphate of potash to an infected field, as regards its capacity of reducing the degree of infection. The results obtained did not show any marked difference between the degree of attack in fields receiving no potash manure and those receiving 100,200, and 300 kilogrammes of Sulphate of potash per feddan.

This experiment will be repeated in pots to find the effect of this manure when thoroughly mixed with infected soil.

In the second case the direct relation between the amount of infecting matter and the infective capacity of the soil was investigated in the following manner : Three lots of Nile-mud, known to be free from the disease were infected with cultures of the parasite grown on acid potato plug (M. 3) as follows :—

Lot *a* received 20 grammes of parasitic culture per 10 kilogrammes of soil or 0·2 per cent.

Lot *b* received 80 grammes of parasitic culture per 10 kilogrammes of soil or 0·8 per cent.

Lot *c* received 160 grammes of parasitic culture per 10 kilogrammes of soil or 1·6 per cent.

The infected soil of each lot was put in sterilised pots. The pots were divided into two lots of equal numbers and each lot sown, one with Sakel and other with Ashmouni cotton seeds.

Table 15 shows the result and the percentage of infection in each lot.

TABLE 15.—SHOWING THE RESULT OF INFECTION IN EACH LOT, RECEIVING DIFFERENT AMOUNTS OF INFECTION.

Variety of cotton.	Lot *A*. Receiving 20 grm. culture.				Lot *B*. Receiving 80 grm. Culture.				Lot *C*. Receiving 160 grm. Culture.			
	Total.	Healthy.	Diseased.	Per cent.	Total.	Healthy.	Diseased.	Per cent.	Total.	Healthy.	Diseased.	Per cent.
Sakel	49	48	1	2	46	42	4	8	34	28	6	17
Ashmouni ...	56	56	0	0	60	60	0	0	47	47	0	0

From table 15 it can be clearly seen that the infective capacity of the soil increases with the addition of parasitic culture.

The results of this test support the suggestion given above relative to the relation between the intensity of infection within the patch in the infected field and the accumulation of the parasite within this patch.

The infective capacity of the soil will be discussed further under " The control of the disease " in part III.

The Relation between the Type of the Soil and its Infective Capacity.

Four types of soil were selected :—

(*a*) Pure sand, (*b*) Light sandy loam, (*c*) Medium loam, (*d*) Heavy clay soil.

These four types were all equally infected, the contents of 200 culture tubes (18 cm. × 18 mm.) of the parasite being added to the cubic metre. No manure was added, Sakel cotton was grown in pots. Table 16 gives the result obtained.

TAPLE 16.—SHOWING THE TYPES OF SOIL AND THEIR INFECTIVE CAPACITY WHEN ALL HAD RECEIVED EQUAL AMOUNTS OF PARASITIC CULTURE (SAKEL COTTON GROWN).

Type of soil.	Total plants.	Healthy.	Diseased.	Percentage of diseased.
Pure sand ...	143	129	14	9·7
Light sandy loam	198	181	17	8·5
Medium loam ..	110	40	70	63·6
Heavy clay ...	109	22	87	79·8

The results show that in light sandy loam and pure sand infection is least, in heavy clay infection is most, while in medium loam it is less.

Though the same number of seeds were sown in each test, it is difficult to account for the great variation of total number of plants.

The relation between the Organic Matter present in the Soil and the Infective Capacity.

The *Fusarium* parasite of cotton being capable of saprophytic activity, the organic content of the soil has naturally an important influence on its saprophytic and parasitic life in the soil : In presence of organic matter the fungus grows in the soil, infecting matter increases and the soil becomes more infective.

To test the above statement, a quantity of soil of known infective capacity (Gemaiza plot 26) was divided into three equal lots ; each lot received a known amount of manure as stated below, Sakel cotton was sown. The results are given in table 17.

TOTAL 17.—SHOWING THE RELATION BETWEEN THE INFECTIVE CAPACITY OF THE SOIL AND ITS ORGANIC CONTENTS.

Quantity of manure added.	Total number of plants.	Diseased plants.	Percentage of diseased plants.
One part of manure to 5 parts of soil	76	27	35·5
One part of manure to 3 parts of soil	78	40	51·2
One part of manure to 1 part of soil	80	67	83·7

From the results shown in table 17, it can be seen that the amount of manure added has a direct influence on the infective capacity of the soil.

Another question which was investigated relative to the infective capacity of the soil is the depth to which the parasite can be found. Soil from an infected field at Gemaiza (plot 26) was taken as follows :—

An area of a square metre within an infected patch was marked. The soil of five successive layers 20 cm. thick was put each in a sepa-

rate sack. The sacks were sent to Giza and the contents of each placed respectively in sterilised pots, and sown with Sakel seed.

Table 18 gives the results.

From table 18 it can be seen that the parasite is present as deeply buried as between 81–100 cm. in the Gemaiza field, and that the most infective layers are those lying between 0 and 40 cm. deep.

TABLE 18.—SHOWING THE DISTRIBUTION OF THE PARASITE WITHIN THE SOIL.

Depth to which soil is taken.	Total.	Healthy.	Diseased.	Per cent.
0— 20 cm.	133	62	71	53·3
21— 40 cm.	133	97	36	27
41— 60 cm.	142	137	5	3·5
61— 80 cm.	97	94	3	3
81—100 cm.	126	119	7	5·5

Other Factors influencing Infection.

From the investigation carried out to study the distribution of the parasite within the soil, it can be seen, as shown in table 18, that the parasite can be found as deeply buried as between 81 and 100 cm. in the soil.

The importance of the distribution of the parasite within the soil became apparent in testing the resistance of selected plants during 1924.

In October 1923 apparently resistant Sakel plants were selected in the Provinces to test the resistance of their progeny. It was necessary to grow them in infected soil. The soil of the Giza experiment farm is as already mentioned free from this disease. At that period of the investigation (1924) it was thought that to expose a plant to disease it would be sufficient to place a culture of the parasite with the seed at sowing in the field.

On sowing the seeds of the selected Sakel plants, the contents of a culture of the parasite on acid potato plug (M. 3) were broken up with a little water and placed with the seed. As a check to the efficacy of this method of infection, a strain of a known susceptible Sakel cotton was sown in the same manner.

After picking the crop, the plants were pulled up and their roots examined for the presence of the characteristic discoloration. Contrary to what was expected in the case of the known susceptible cotton,

only a few plants showed typical discoloration, while the majority of the others had only a limited discoloration, nearly black in colour, in the tissue of the root or the hypocotyl.

The discoloration was somewhat similar to that occurring in some of the Ashmouni cotton plants growing in Upper Egypt as already described, Fig. 13.

Similar discoloration was also found in some plants grown from the seed of the selected plants, Fig. 28 shows the slit roots of some of these plants, normally infected roots are also shown to the right and one healthy root to the left of the photograph for comparison.

Isolations were made from the limited discoloured portions of these plants and some gave pure culture of a *Fusarium* which on being tested proved parasitic on Sakel cotton grown in pots.

The *Fusarium* used to infect the field as described above, was without doubt parasitic, as it was capable of infecting the same strain of susceptible Sakel as grown in the check, when this cotton was sown in pots (14×12×24 cm.) to which the contents of one culture tube (18 cm. × 18 mm.) per pot of this *Fusarium* was added. The main difference between the two methods of infection was that in the case of the field infection, the culture was placed with the seed, while in the pot infection, the soil was thoroughly mixed with the culture before sowing.

From the above results, it seems to the author, that the plants showing the limited abnormal discoloration got infected at the seedling stage, but as their roots grew into clean soil, they were able to make vigorous growth in the absence of the parasite. The plant became then better able to check the spread of the parasite which had penetrated its tissue, by forming a barrier of cells impregnated with the black gum-like substance, which forms the abnormal limited discoloured areas.

The depth of infected soil is therefore an important factor in influencing infection.

Anothor factor which may influence infection is the possibility of the formation of some detrimental substances in infected soil.

These substances which may be in the form of bye-products of the fungus excreted or secreted during its growth, may act detrimentally on the plant growing in such soils, and weaken its constitution so as to make it fall an easy victim to this disease.

This is only a hypothesis, the truth of which requires investigation. The author is however inclined to believe that in the case of the well distributed soil infection, similar to that which occurs under natural field conditions, the plant is subjected to many repeated infections as its roots grow in soil containing the parasite. The plant is unable to resist, for the new roots as they grow into the soil are subjected to fresh attacks. This question is gone into with some details in part III.

THE RELATION BETWEEN THE ROTATION AND SEVERITY OF THE DISEASE.

The frequency of sowing susceptible cotton seems to increase the severity of the disease. An interesting example of this is the rotation experiment at Gemaiza farm.

The Cotton Research Board of this Ministry started in 1922 a rotation experiment at Gemaiza farm with the object of studying the effect of rotation on the yield of cotton.

The rotation experiment consists of :—

(1) One year rotation, *i.e.*, cotton every year on the same land.

(2) Two years rotation, *i.e.*, cotton every two years on the same land.

(3) Three years rotation, *i.e.*, cotton every three years on the same land.

In all cases the variety of cotton grown was Sakel.

Rotation 1 consists of six plots yearly under cotton.

Rotation 2 consists of 2 lots (*a*) and (*b*) of six plots each.

In this way six lots are yearly under cotton.

Similarly Rotation 3 consists of three lots (*a*), (*b*) and (*c*) of six plots each, one lot of which is yearly under cotton.

In each case, the area of each plot is half a feddan.

The following tables 19, 20, 21 show the different rotations in detail :—

TABLE 19.—SHOWING THE ONE YEAR ROTATION.

Month of the year.	Crop.
October	
November	Temporary Berseem.*
December	
January	
February	
March	Cotton.
April	
May	
June	
July	
August	
September	

5 cubic meters of farm yard manure are applied per feddan after the berseem crop and before cotton.

* Temporary Berseem is a catch crop of clover cut once and rarely twice.

TABLE 20.—SHOWING THE TWO YEARS ROTATION.

Month of the year.	Lot (*a*) Crop.	Lot (*b*) Crop.
October	Temporary Berseem.	* Permanent Berseem. (Half each plot). Wheat. (Other half of each plot).
November		
December		
January		
February		
March	Cotton.	
April		
May		
June		
July		Maize.
August		
September		
October	* Permanent Berseem. (Half each plot).	
November	Wheat. (Other half of each plot).	
December		
January		
February		
March		Cotton.
April		
May		
June		
July	Maize.	
August		
September		

(1) 20 cubic meters of farm yard manure are applied per feddan for maize (at Tafi el Sharaki)†

(2) 100 kilogrammes of Sodium Nitrate are applied per feddan for the wheat crop.

* Permanent Berseem is a clover crop cut several times and finally left for seed.

† Irrigation after barefallow following winter crops (wheat, permanent berseem, etc.).

TABLE 21.—SHOWING THE THREE YEARS ROTATION.

Month of the year.	Lot (*a*) Crop.	Lot (*b*) Crop.	Lot (*c*) Crop.
October	Temp. Berseem.	—	Perm. Berseem.
November	—	Wheat.	—
December	—	—	—
January	—	—	—
February	—	—	—
March	Cotton.	—	—
April	—	—	—
May	—	—	—
June	—	—	—
July	—	Maize.	—
August	—	—	—
September	—	—	—
October	Perm. Berseem.	Tem. Berseem.	—
November	—	—	Wheat.
December	—	—	—
January	—	—	—
February...	—	—	—
March	—	Cotton.	—
April	—	—	—
May	—	—	—
June	—	—	—
July	—	Maize.	—
August	—	—	—
September	—	—	—
October	—	Perm. Berseem.	Tem. Berseem.
November	Wheat.	—	—
December	—	—	—
January	—	—	—
February	—	—	—
March	—	—	Cotton.
April	—	—	—
May	—	—	—
June	—	—	—
July	Maize.	—	—
August	—	—	—
September	—	—	—

No manure is applied to the plots under this rotation.

In 1924 the cotton plants growing in the one year rotation plots were reported to have suffered from this disease, but due to pressure of work the author was unable to examine the matter closely.

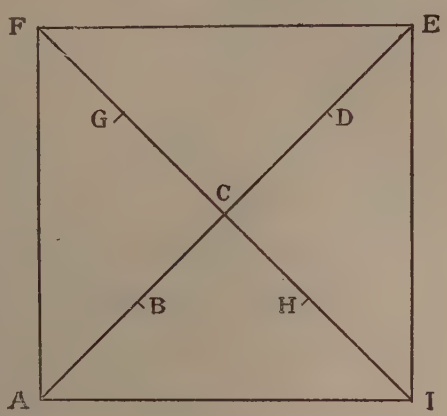
In 1925 the matter was considered and the following investigation was carried out to find if the intensity of the disease increases with the frequency of sowing cotton on the same land.

After the second pick the percentage of the diseased plants growing diagonally across each plot under cotton was calculated.

For the sake of clearness, let the following diagram A F E I represent one of the plots under cotton.

A E and F I represent the diagonals.

These diagonals were each similarly divided into four equal parts. The cotton plants growing between A and B, B and C, C and D, D and E, F and G, G and C, C and H, H and I, were pulled up and each lot examined for the presence of the characteristic discoloration by slitting their roots, and the percentage of diseased plants to total pulled plants was calculated.



In 1926 the same operations were repeated. The number of missing plants in the one year rotation plots where the disease was most severe was approximately estimated.

Table 22 gives the percentage of infection in each plot and per rotation under cotton for the years 1925 and 1926.

Table 22.—Showing the Percentage of Infection in the Plots under the different Rotations.

Rotation.	No. Plot.	Year.	Approx. Percentage of missing plants.	Percentage of Diseased Plants.										Remarks.
				A–B.	B–C.	C–D.	D–E.	F–G.	G–C.	C–H.	H–I.	Average.	% Average per rotation.	
One Year.	1	1925	—	82	40	68	74	74	43	78	53	64	—	Under cotton in 1923, 1924, 1925 and 1926
	—	1926	40	75	93.3	100	96.6	86.6	100	73.3	86.6	88.8	—	
	7	1925	—	93	100	85	92	100	100	100	93	95	—	
	—	1926	75	73.3	56.2	23·3	60	70	66.6	53.3	60	61.5	—	
	14	1925	—	100	93	100	100	87	90	93	84	93	—	
	—	1926	70	86.6	43.7	45	73.3	60	43.7	74	66.6	61.2	—	

TABLE 22 (*contd.*).

Rotation.	No. Plot.	Year.	Approx. Percentage of missing plants.	Percentage of Diseased Plants.										Remarks.
				A–B.	B–C.	C–D.	D–E.	F–G.	G–C.	C–H.	H–I.	Average.	% Average per rotation.	
One Year (*contd.*).	20	1925	—	58	85	84	90	73	85	73	66	75	—	
	—	1926	30	80	76.6	70	96.6	80.6	86.6	100	100	86.3	—	
	26	1925	—	93	100	100	90	80	75	100	100	92	—	
	—	1926	70	73.3	56.2	46.6	60	73.3	62.5	26.6	75	59.3	—	
	33	1925	—	60	66	73	83	64	93	76	53	71	—	
	—	1926	40	87.5	80	90	86.6	100	93.3	83.8	93.3	89.3	—	
	average	1925	—	—	—	—	—	—	—	—	—	—	76	
		1926	54.1	—	—	—	—	—	—	—	—	—	74.5	
Two Years.	2	1925	—	25	15	6	30	26	8	3	9	15	—	Under cotton in 1923 and 1925
	8	,,	—	43	35	33	25	31	22	56	100	42		
	13	,,	—	25	18	20	33	73	43	22	43	35		
	24	,,	—	37	19	25	31	50	16	23	13	27	—	
	30	,,	—	23	29	6	21	10	23	30	10	19	—	
	36	,,	—	21	12	6	12	10	25	21	15	15	—	
	average	—	—	—	—	—	—	—	—	—	—	—	25	
	21	1926	—	30	23.3	33.3	25.8	26.6	33.3	50	48.3	33.8	—	Under cotton in 1924 and 1926
	32	,,	—	25	43.7	35.4	30	33.3	56.2	26.6	43.7	37	—	
	27	,,	—	33.3	20	43.3	46.8	66.6	53.3	40	19.3	40.3	—	
	10	,,	—	13.3	9	20	31·2	37.5	10	33.3	25.8	22.7	—	
	4	,,	—	66.6	43.7	16.3	26.6	13.3	33.3	26.6	20	30.5	—	
	16	,,	—	40	26.6	20.6	37.5	56.2	32.2	43.7	33.3	36.4	—	
	ver	—	—	—	—	—	—	—	—	—	—	—	33.5	

TABLE 22 (*contd.*).

Rotation.	No. Plot.	Year.	Approx. Percentage of missing plants.	PERCENTAGE OF DISEASED PLANTS.										Remarks.
				A–B.	B–C.	C–D.	D–E.	F–G.	G–C.	C–H.	H–I.	Average.	% Average per rotation.	
Three years.	6	1925	—	20	35	6	7	3	18	30	17	17	—	Not Under cotton in 1922
	11	,,	—	14	6	16	9	0	0	6	3	6	—	
	17	,,	—	15	25	9	23	31	13	4	22	16	—	
	23	,,	—	7	10	10	21	0	3	6	0	7	—	
	28	,,	—	12	10	16	10	0	10	0	16	9	—	
	34	,,	—	6	3	0	6	12	0	10	0	4	—	
	average	,,	—	—	—	—	—	—	—	—	—	—	10	
	29	1926	—	26.6	25.8	20	12.5	16	25.8	20	21.8	21	—	under cotton in 1923
	22	,,	—	12.5	30	20	23.3	0	25	6.6	29	18.3	—	
	35	,,	—	20	12.9	30	26.6	33.3	31.2	26.6	16.1	24.5	—	
	3	,,	—	31.2	13.3	16.1	13.3	13.3	0	26.6	13.3	16	—	
	15	,,	—	37.5	26.6	38.7	33.3	36.6	28.1	36.6	31.2	33.6	—	
	9	,,	—	26.6	30	31.2	6.6	20	12.9	43.7	37.5	36.3	—	
	average	—	—	—	—	—	—	—	—	—	—	—	23·2	

The results given in table 22 show the following :—

(1) That the degree of the attack increases with the frequency of growing cotton, *i.e.*, in the plots under one year rotation (cotton every year) the attack is greater than in the plots under the two years rotation (cotton every two years) while in the plots under the three years rotation the average attack is least of all.

(2) That the infection is unevenly distributed in the least infected plots (plots No. 11, 23, 28, 34, etc.) but as the disease increases the infection becomes more or less uniformly distributed throughout the field, until finally the whole field becomes involved.

(3) That the different plots under one rotation do not show the same degree of infection. This is more apparent in the case of the three years rotation plots.

(4) That in the one year rotation, when the infective capacity of the soil reaches a certain degree (above 75 %) as in plots Nos. 7, 14 and 26 (1925), the number of missing plants is greater the following year (1926) than in plots with a lower infective capacity (1925) as in plots Nos. 1, 20 and 33. This seems to be due to the early death of a greater number of plants owing to the heavy infective capacity of the soil (in plots Nos. 7, 14, and 26); a fact which has been repeatedly observed in heavily infected fields in different parts of the Delta.

The following list illustrates the above :—

Plot No.	Percentage of		
	Infected plants.		Missing plants.
	1925.	1926.	1926.
1	44	88·8	40
7	95	61·5	75
14	93	61·2	70
20	75	86·3	30
26	92	59·3	70
33	71	89·3	40

(5) On the other hand the percentage of infection in surviving plants at the end of the season of 1926 in plots Nos. 7, 14, 26 appears at first sight less than in the other plots Nos. 1, 20 and 33. This seems to be due to the fact that in the more heavily infective plots (7, 14 and 26) many of the more susceptible plants die at an early age, leaving the less susceptible to continue their growth to the end of the season. Of these the percentage which get infected is naturally less than in the case, had the more susceptible plants survived.

Samples of soil from all the different rotation plots (1925) as mentioned in table 22 were sent to the Chemical Section of this Ministry for analysis of the total soluble salts, sodium carbonate, sodium bicarbonate, sodium chloride and pH. values.

The results are given in table 23.

TABLE 23.—RESULTS OF ANALYSIS (1925).

(Percentage of Air Dried Soil).

ONE YEAR ROTATION.

PLOT NO.	1	7	14	20	26	33
Total Soluble Salts	0·16	0·20	0·16	0·20	0·16	0·16
Sodium Carbonate	traces.	traces.	traces.	traces	0·01	traces.
„ Bicarbonate	0·20	0·20	0·23	0·23	0·19	0·20
„ Chloride...	0·03	0·02	0·02	0·02	0·02	0.03
pH*...	8	8	8·5	8·5	8	8

TWO YEARS ROTATION.

PLOT NO.	2	8	13	24	30	36
Total Soluble Salts	0·18	0·16	0·14	0·18	0·18	0·16
Sodium Carbonate	0·01	0·01	0·01	traces.	traces.	traces.
„ Bicarbonate	0·20	0·21	0·19	0·20	0·20	0·21
„ Chloride...	0·02	0·02	0·02	0·02	0·02	0·02
pH*...	8·5	8·5	8	8	8·5	8

THREE YEARS ROTATION.

PLOT NO.	6	11	17	23	28	34
Total Soluble Salts	0·18	0·16	0·14	0·18	0·20	0·20
Sodium Carbonate	traces	traces.	traces.	traces.	traces.	traces.
„ Bicarbonate	0·21	0·19	0·21	0·20	0·20	0·21
„ Chloride...	0·02	0·02	0·02	0·04	0·04	0·02
pH*...	8·5	8·5	7·5	8	8	8

Hardly any information on the relation between the salt contents of the soil of these plots and the amount of infection could be gained from this chemical analysis.

The soils of these plots are all alkaline as shown by the pH values.

The reason for the increase of infection in the one year rotation more than in the two years rotation, and in the two years rotation more than in the three years rotation seems to the author, to be due to the increase of infective matter which accumulates with the frequency of susceptible cotton growing in the respective rotations.

The Relation between the Yield and the Severity of the Disease.

The yields of the plots under the one, two and three years rotations are given in table 24.

* The pH value was estimated by the colorimetric method.

TABLE 24.—SHOWING THE YIELD OF THE ROTATION AND THE AVERAGE DEGREE OF INFECTION IN 1925 AND 1926.

Rotation.	Plot No.	1923. Yield in rotls.* Per plot.	1923. Yield in rotls.* Average per feddan.	1924. Yield in rotls.* Per plot.	1924. Yield in rotls.* Average per feddan.	1925. Yield in rotls.* Per plot.	1925. Yield in rotls.* Average per feddan.	Percentage of disease. Per plot.	Percentage of disease. Per rotation.	1926. Yield in rotls.* Per plot.	1926. Yield in rotls.* Average per feddan.	Percentage of disease. Per plot.	Percentage of disease. Per rotation.	Loss of yield per feddan. Years.	Loss of yield per feddan. Rotls.
One year rotation.	1	847		576		577		44		350		88·8			
	7	765		334·5		377		95		134		61·5			
	14	871		439·5		462		93		71		61·2			
	20	1,113		585·5		695		75		267		86·3			
	26	945		344·5		508		92		180		59·3			
	33	985		500·75		678		71		189		89·3			
			1,842		926		1,099		76		397		74·5	1923–1926	1,445
Two years rotation.	2	734				758		15							
	8	779				739		42							
	13	824				674		35							
	24	851				813		27							
	30	867				720		19							
	36	1,000				840		15							
			1,685				1,515·15		25					1923–1925	169·85
	4			589·25						503		50·3			
	10			728·50						756		22·7			
	16			588·75						534		36·4			
	21			699·75						623		33·8			
	27			566·5						606		40·3			
	32			620·75						648		37			
					1,264·1						1,127·7		35·5	1924–1926	136·4

Three years rotation.	3	793													
	9	801													
	15	909													
	22	813													
	29	875													
	35	1,047													
			1,745·1												
	5			620·50											
	12			679·50											
	18			633·50											
	19			776·75											
	25			621·50											
	31			616·75											
					1,316·16										
	6					786		17							
	11					805		6							
	17					838		16							
	23					809		7							
	28					802		9							
	34					910		4							
							1,650·6		10						
	3									589		16			
	9									511		26·3			
	15									696		33·6			
	22									683		18·3			
	29									613		21			
	35									632		24·5			
											1,115·1		23·2		

* *See* Appendix.

Resumé of Table 24.

Rotation.	1923.	1924.	1925.	Percent. of disease.	1926.	Percent, of disease.	Loss of Yield.	
	Yield per feddan. (rotls).	Yield Per feddan. (rotls).	Yield per feddan. (rotls).	per rotation.	Yield per feddan. (rotls).	Per rotation.	Year.	Rotls.
One Year Rotation.	1,842	926	1,099	76	397	74·5 + 54·1 Miss-ing plants	1923–1926	1,445
Two Years Rotation.	1,685	—	1515·15	25	—	—	1923,1925	169·85
	—	1264·1	—	—	1127·7	33·5	1924,1926	136·4
Three Years Rotation.	1745·1	—	—	—	—	—	—	—
	—	1316·16	—	—	—	—	—	—
	—	—	1650·6	10	—	—	—	—
	—	—	—	—	1115·1	23·2	—	—

Owing to the irregularity of the figures given in table 24, no definite conclusions can be arrived at.

In the case of the one year rotation, however, the drop of the yield for the year 1926 is very striking and seems to be due to the high percentage of missing plants, the majority of which had died from the disease.

Mr. M. A. Baily, now Chief Botanist to the Sudan Government writes to the author relative to this question: "Results worth considering cannot be expected to arrive from a rotation experiment until it has been going quite 10 years and where the plot error is so high, the period would have to be longer still."

PART II.—THE RELATION BETWEEN THE EGYPTIAN FUSARIUM, THE INDIAN FUSARIUM AND FUSARIUM VASINFECTUM.

To attempt to identify the Egyptian *Fusarium*, it was found necessary to compare it with the Indian and American fungi producing wilt diseases in these respective countries.

The morphological differences between the microconidia and macroconidia of these three fungi are too small to be of any value in differentiating these fungi.

There is, however, some difference in the morphology of the chlamydospores, substratum colouration and cultural characters of these respective fungi.

The Chlamydospore Differences.

These three fungi were grown on acid potato plug (M. 3) and examined after 40 days incubation at 30° C.

Table 25 gives the main morphological differences between the chlamydospores of these fungi.

Table 25.—Showing the Principal Morphological Differences between Chlamydospores of the Egyptian, Indian and American Fusarium.

The Egyptian *Fusarium*.	The Indian *Fusarium*.	The American *Fusarium*.
1.–Mycelial :— (1) *Terminal.* 0–1–Septate.	1. Mycelial :— (1) *Terminal.* 0–1–Septate.	I.–Mycelial :— (1) *Terminal.* 0–1–Septate.
The 0–Septate. These are subglobose, rarely spherical. Fig. 35 (1).	The 0–Septate. These are spherical to ovate in shape and are of frequent occurrence. Fig. 41 (1).	The 0–Septate. These are globose to spherical. Fig. 44 (1).
The 1–Septate. These are of equal or unequal size, in the latter case the division next to the myce-	The 1–Septate. These are of equal or unequal size. In the latter case the division next to the myce-	The 1–Septate. These resemble those of the Egyptian *Fusarium*, but are of more frequent occurrence

TABLE 25 (*contd.*).

The Egyptian *Fusarium*.	The Indian *Fusarium*.	The American *Fusarium*.
lium is much smaller, often appearing as a simple swelling at the base of the other. Fig. 35 (2).	lium is sometimes rectangular and has a restricted portion in the middle of its body. Fig. 41 (2).	and often borne on branched short hyphæ Fig. 44 (2).
2.–INTERCALARY. 0–1 Septate. In Chain. In Cluster.	2.–INTERCALARY 0–1 Septate. In Chain. In Cluster.	2.–INTERCALARY 0–1 Septate. In Chain. In Cluster.
The 0–Septate. These resemble the terminal but are not of frequent occurrence. Fig. 35 (3).	The 0–Septate. These are spherical to ovate and sometimes rectangular. Fig. 41 (2.)	The 0–Septate. These are spherical and of frequent occurrence. They occur often at intervals on the same hyphæ giving it a knotted appearance. This is peculiar to this *Fusarium*. Fig. 43 (3).
The 1–Septate. These are generally similar in size and globose in shape. Fig. 35 (4).	The 1–Septate. These are spherical to rectangular, the latter sometimes with a definite restricted waist Fig. 41 (4).	The 1–Septate. These are of equal or unequal size, the shape varies from spherical to rectangular. They are not of frequent occurrence. Fig. 44(4).
In Chain. (*a*) Chlamydospores of equal size. This is not of frequent occurrence.	In Chain. (*a*) Chlamydospores of equal size. This is very rare.	In Chain (*a*) Chlamydospores of equal size. This is of frequent occurrence. Chlamydospores are spherical to globose. Fig. 44 (5).

TABLE 25 (*contd.*).

The Egyptian *Fusarium*.	The Indian *Fusarium*.	The American *Fusarium*.
(*b*) Chlamydospores of unequal size. These are more or less globose in shape, the largest spore being in the middle of the chain, while towards both or one of the extremities of the chain, the chlamydospores are gradually reduced in size. This is characteristic of this *Fusarium*. Fig. 35 (5).	(*b*) Chlamydospores of unequal size. These vary in size and shape from small to large and from spherical to rectangular. As a whole the chlamydospores in chain, in this *Fusarium*, are much rarer than in the Egyptian and the American. Fig. 41 (5).	(*b*) Chlamydospores of unequal size. These vary much in size and shape and are unevenly distributed in the chain, a condition which gives the chain a knotted appearance Fig. 44 (6). This characteristic is similar to what occurs in the case of the 0-Septate intercalary. Fig. 44 (3). Chlamydospores which are often scattered within a hypha give a similar knotted appearance differentiating this *Fusarium* from the other two.
(*c*) Frequently the hypha becomes divided up into short portions. These short thick-coated portions of the hypha may or may not be of equal sizes and are barrel to dumb-bell like in shape. The dumb-bell shaped chlamydospores in chain are gradually reduced in size towards one or both extremities of the chain in a similar manner as those described under (*b*). Fig. 35 (6). Sometimes after the disintegration of the hypha enclosing the chlamydospores, these become liberated and appear as independent dumb-bell shaped chlamydospores.	(*c*) The mycelium becomes divided up into short rectangular thick-coated bodies more or less uniform in shape and size. The dumb-bell shaped chlamydospores have not been observed in this *Fusarium*. Fig. 41 (6).	(*c*) The hypha may become divided into equal portions varying from rectangular to dumb-bell shaped chlamydospores. These are of rarer occurrence than in the case of the Egyptian *Fusarium*. When met with, they are of different size and shape from those of the Egyptian *Fusarium* and lack the characteristic reduction in size towards one or both extremities of the Chain. Fig. 44 (7).

TABLE 25 (*contd.*).

The Egyptian *Fusarium*.	The Indian *Fusarium*.	The American *Fusarium*.
(*d*) Sometimes granulated portions of hyphæ develop thick walls. They may or may not be divided. Fig. 35 (7).	(*d*) Granulated portions of hyphæ also occur in this *Fusarium* and are generally less frequent than in the case of the Egyptian *Fusarium*. Fig. 41 (7).	(*d*) Granulated portions of hyphæ also occur in this *Fusarium* and resemble those of the Indian. Fig. 44 (8).
In Cluster. This is generally rare. Fig. 35 (8).	In Cluster. This has not been observed.	In Cluster. This has been rarely observed.
II. *Conidial.* In old cultures and under reduced aeration microconidia and macroconidia, but mostly the latter, develop intercalary chlamydospores. The walls of the conidium first become thickened in one portion developing thick septa which cut this part from the rest of the body of the conidium. The chlamydospore thus produced is barrel shaped slightly broader than the original width of the conidium, Fig. 35 (9) and Fig. 36.	II. *Conidial.* Similar to that of the Egyptian *Fusarium* with the exception that more frequently some of the microconidia may be wholly granulated with a definite thick coat and with or without septation. Fig. 41 (8) and Fig. 42.	II. *Conidial.* Attempts to make this *Fusarium* produce conidial chlamydospores, have up to now failed.

From table 25 it can be seen that though the difference between the chlamydospores of the three *Fusarium* fungi under discussion is small, this difference, however, as far as the conditions under which this study was conducted, is enough to permit the separation of these fungi from each other.

It is difficult, at the present stage of this investigation to say if these differentiating characters of the chlamydospores of these three

fungi are constant enough to be considered of real value as permanent differentiating characters.

It may be just as well to enumerate the outstanding differentiating characters :—

In the case of the Egyptian fungus the chlamydospores in chain have frequently the characteristic appearance of the spores being gradually reduced in size towards the one or both extremities of the chain.

Another character of the Egyptian *Fusarium* is the frequent occurrence of chains of dumb-bell shaped chlamydospores.

The Indian *Fusarium*, in the case of the 1 septate terminal chlamydospore, has frequently the division next to the mycelium rectangular in shape and definitely restricted at its centre.

The American *Fusarium* has the peculiar knotted appearance due to hyphæ containing spherical to globose non-septate intercalary chlamydospores and to the uneven size of the chlamydospores, in chain, in some cases.

The types of growth and substratum colouration of the Egyptian, Indian and American Fusarium.

These fungi were compared and the result is given in table 26.

TABLE 26.—SHOWING THE TYPES OF GROWTH AND SUBSTRATUM COLOURATION OF FUSARIUM EGYPTIAN, FUSARIUM INDIAN AND FUSARIUM VASINFECTUM, ON DIFFERENT MEDIA WHEN 21 DAYS OLD, INCUBATION BEING AT 30° C.

Fusarium.	Medium.	Growth.	Hyphæ.	Spores.	Substratum Colouration.
Egyptian. Culture: No. 2038.	Rice (M. 5.)	Fair.	Much branched, some much granulated.	Microconidia 0–Septate present, macroconidia not observed, chlamydospores not observed, some short hyphæ attempting chlamydospore formation.	Yellow brilliant(6) with light cobalt violet (4) in parts. Fig. 50.

TABLE 26 (*contd.*).

Fusarium	Medium.	Growth.	Hyphæ.	Spores.	Substratum Colouration.
Indian. Culture: No. 2048.	Rice (M. 5.)	Better than that of Culture No. 2038.	Majority not granulated, less branched than that of culture No. 2038.	Microconidia 0-Septate present, macroconidia not observed, chlamydospores few, very short portions of hyphæ, much granulated and thick walled are present.	Light cobalt violet(4) madder lake in patches (5) ring deep mineral violet. (1) Fig. 50.
Vasinfectum. Culture: No. 2058.	Rice (M. 5.)	Excellent, much better than that of cultures No. 2038 and No.2048.	Similar to that of culture No. 2048.	Microconidia very abundant, majority 0-Septate, macroconidia very rare, chlamydospores rare, few short granulated, thick walled portions of hyphæ somewhat similar to those of culture No. 2048.	Aring of deep mineral violet (1). Fig. 50.
Egyptian. Culture: No. 2043.	Potato Agar + 2 % Dextrose (M. 6.)	Poor and slimy.	Poorly developed.	Microconidia 0-Septate present, Macroconidia not observed. No chlamydospores observed.	None.

TABLE 26 (*contd.*).

Fusarium.	Medium.	Growth.	Hyphæ.	Spores.	Substratum Colouration.
Indian. Culture: No. 2053.	Potato Agar + 2 % Dextrose (M. 6.)	Poor and slimy.	Poorly developed, some are much granulated.	Microconidia 0-Septate present, Macroconidia not observed, Chlamydospores rare, many short thick walled portions of granulated hyphæ present.	None.
Vasinfectum. Culture: No. 2063.	Potato Agar + 2 % Dextrose (M. 6).	Better than that of culture No. 2043 and No. 2053.	Normal, similar to that of culture No. 2066, majority not granulated.	Microconidia 0-Septate present, Macroconidia not obseved chlamydospores not observed.	None.
Egyptian. Culture: No. 2044.	Potato Agar + 5 % Dextrose (M, 7).	Better than that of Culture No. 2043.	Normal, majority similar to that of culture No. 2046 but not granulated.	Microconidia 0-Septate abundant, Macroconidia very rare, Chlamydospores rare, some hyphæ attempting chlamydospore formation.	None.
Indian. Culture: No. 2054.	Potato Agar + 5 % Dextrose (M. 7.)	Better than that of culture No. 2044.	Majority granular.	Microconidia 0-Septate present, Macroconidia not observed, chlamydospores rare.	Very light mineral violet (1) in limited areas. Fig. 50.

TABLE 26 (*contd.*).

Fusarium.	Medium.	Growth.	Hyphæ.	Spores.	Substratum Colouration.
Vasinfectum. Culture: No. 2064.	Potato Agar + 5 % Dextrose (M. 7.)	Similar to that of culture No. 2054.	Similar to that of culture No. 2054.	Microconidia 0-Septate abundant. Macroconidia very few. Chlamydospores present, some hyphæ attempting chlamydospore formation.	Light mineral violet (1) but deeper than that of culture No. 2054 Fig. 50.
Egyptian. Culture: No. 2045.	Oatmeal Agar. (M.8).	Poor	Majority not granular with a tendency to form chlamydospores.	Microconidia, majority 0-Septate, Macroconidia not observed, completely formed chlamydospores not observed.	Traces permanent mauve (2) of different shades. Fig. 50.
Indian. Culture: No. 2055.	Oatmeal Agar. (M.8).	Fair.	Majority branched and some granulated.	Microconidia 0-Septate present, Macroconidia not observed. Chlamydospores mostly terminal, 0-1 Septate.	Combination of cobalt violet (4) and mauve (3) Fig. 50.
Vasinfectum. Culture: No. 2065.	Oatmeal Agar. (M.8).	Fair.	Normal, Similar to that of culture No. 2066, some granulated.	Microconidia 0-Septate abundant, Macroconidia rare chlamydospores few, mostly intercalary.	Combination of deep mineral violet (1) and light mauve (3) Fig. 50.

TABLE 26 (*contd.*).

Fusarium.	Medium.	Growth.	Hyphæ.	Spores.	Substratum Colouration.
Egyptian. Culture: No. 2046.	Acid Potato plug (M.3).	Excellent.	Normal, branched, few are granulated.	Microconidia abundant 0-Septate, Macroconidia few, Chlamydospores mostly intercalary some in clusters.	None.
Indian. Culture: No. 2056.	Acid Potato plug. (M.3).	Good.	Normal, majority not granular and less branched than that of Culture No. 2046.	Microconidia very abundant 0-Septate, Macroconidia few, Chlamydospores present mostly terminal.	Mauve (3) deeper in rings. Fig. 50.
Vasinfectum. Culture: No. 2066.	Acid Potato plug. (M.3.)	Excellent.	Normal, few are granular less branched than that of culture No. 2046.	Microconidia 0-1 Septate in very great number, Macroconidia few, Chlamydospores many mostly intercalary.	Light mauve (3) deeper in rings. Fig. 50.
Egyptian. Culture: No. 2047.	Potato plug. (M.9).	Not so vigorous as that of Culture No. 2046.	Similar to that of Culture No. 2046.	Similar to that of Culture No. 2046.	None.

TABLE 26 (*contd.*).

Fusarium.	Medium.	Growth.	Hyphæ.	Spores.	Substratum Colouration.
Indian. Culture: No. 2057.	Potato plug. (M.9).	Not so vigorous as that of No. 2056.	Similar to that of Culture No. 2056.	Similar to that of Culture No. 2056.	Very light mauve (3) Fig. 50.
Vasinfectum. Culture: No. 2057.	Potato plug. (M.9).	Not so vigorous as that of Culture No. 2056.	Similar to that of Culture No. 2056.	Similar to that of Culture No. 2056.	Very light mauve (3) Fig. 50.

Figure 50 shows a coloured drawing of cultures of the Egyptian, Indian and American *Fusarium* parasites of cotton on rice and oatmeal agar media ; the colours* entering into the substratum colouration are also given, these are :—

No. 1.—Mineral violet.
No. 2.—Mineral Mauve (given as permanent mauve*).
No. 3.—Violet Mauve (given as mauve 2*).
No. 4.—Cobalt Violet.
No. 5.—Madder Lake.
No. 6.—Brilliant yellow.

When a lighter shade of the above-mentioned colours was observed the word "light" is stated.

From table 26 it can be seen that these *Fusarium* parasites causing the wilt disease in Egypt, India and the States are distinctly different as to their capacity of growth and substratum colouration.

The differences are so apparent that these *Fusarium* parasites cannot be considered identical though producing the same disease in different countries.

This result seems, to the author, of importance, because it suggests that other parasites producing the same diseases in different countries may also be similarly different as the *Fusarium* parasites under consideration.

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* Specimen Tints of Winsor and Newton's "Artists' oil and water colours" (Rathbone Place, London W.) was used as reference.

Note.—The culturs used for the comparison are :—

Egyptian *Fusarium* : Strain No. 7.

Indian *Fusarium* : received from Mr. G. S. Kulkarni, Cotton Special Mycologist, Dharwar, India.

Fusarium vasinfectum received from Mr. E. W. Mason, of the Imperial Bureau of Mycology, Kew, who writes "I am forwarding to you the best strain of *Fusarium vasinfectum* that we have."

The Parasitism of Fusarium Vasinfectum and Fusarium Indian as compared with that of Fusarium Egyptian.

In 1924 the author received the following *Fusarium* cultures :—

A culture of *Fusarium vasinfectum* received from Dr. Gilbert of the Bureau of Plant Industry Department of Agriculture (U.S.A.) under No. 1651.

Cultures of *Fusarium vasinfectum* received from Dr. Sherbakoff of Knoxville Tenessee (U.S.A.) under Nos. 873 *a*, 852 *a*, and 706.

Cultures of *F. vasinfectum* received from Dr. Ludwing of Clemson College giving dates of isolation and of subsequent transfers (Tay 7/9, 7/12, 7/17).

Cultures of *Fusarium* parasitic on cotton in India received from Mr. G. S. Kulkarni, Dharwar, under No. 5424 *a*.

These fungi were respectively transferred on acid pottao plug medium (M. 3). When growth was full after 10 days incubation at 30° C, the respective cultures were broken up, each lot separately in a known amount of water. The different culture suspensions thus obtained were each mixed up separately with a known amount of dried Nile mud known to be free from the Egyptian *Fusarium* disease of cotton.

An equal number of sterilised pots was filled with the different lots of infected soil. Each lot of pots was placed far enough from one another to prevent the possibility of infection occurring from one lot to the other through the possible splashing during the watering of the pots.

An equal number of pots was filled with soil (Nile mud) infected with the Egyptian *Fusarium*, for the purpose of comparison.

Table 27 shows the result.

TABLE 27.—SHOWING PARASITISM OF FUSARIUM VASINFECTUM AND INDIAN FUSARIUM AS COMPARED WITH THAT OF EGYPTIAN FUSARIUM.*

Variety of Cotton.	Gilbert's		Sherbakoff's 873 a		Sherbakoff's 852 a		Sherbakoff's 843		Sherbakoff's 706		Ludwig's		Indian		Egyptian	
	No. of Plants.		No. of Plants.								No. of Plants.		No. of Plants.		No. of Plants.	
	Healthy.	Diseased.	Healthy.	Diseased.	Healthy.	Diseased.	Healthy.	Diseased.	Healthy.	Diseased.	Healthy.	Diseased.	Healthy.	Diseased	Healthy.	Diseased.
Sakel ...	49	5	12	0	12	0	12	1	12	0	24	2	12	0	22	18
Ashmouni.	55	0	12	0	12	0	12	0	12	0	31	2	12	0	20	0
Zagora ...	43	0	17	2	21	0	26	0	24	0	33	1	12	0	16	0

* The occurrence of disease was recorded on al plants up from the seedling-stage until maturity.

The above preliminary test shows that there is a marked difference between the parasitism of *F. vasinfectum* the Indian *Fusarium* and the Egyptian *Fusarium*.

In 1925 it was found desirable to repeat this test but on a much larger scale using the Egyptian, Indian fungi and a mixture of all the different cultures of *Fusarium vasinfectum* received in 1924, and a much greater number of different cotton varieties. This test was again repeated in 1926.

The two tests were otherwise similar to that carried out during the previous year (1924).

Table 28 shows the susceptibility of the Egyptian cotton varieties, table 29 shows the susceptibility of the American cotton varieties while table 30 shows the susceptibility of the Indian cotton varieties.

In all cases equal amounts of culture were used to infect equal quantities of soil.

In both the preliminary and this test, plants were considered diseased when they showed a discoloration at the central cylinder of their roots and gave on isolation a *Fusarium* morphologically identical to the parasite.

The results shown in tables 28, 29 and 30 show clearly, as far as the conditions under which these tests were carried out, that the Egyptian, American and Indian *Fusarium* parasites are different as to their parasitism.

It seems to the author, as far as the present results go and under Egyptian conditions that :—

(1) *Fusarium vasinfectum* is a very weak parasite on Egyptian cotton and non-parasitic on the Indian varieties.

(2) The Indian *Fusarium* is non-parasitic on both the American and the Egyptian varieties and parasitic on some of the Indian varieties used.

(3) The Egyptian *Fusarium* is a powerful parasite on the long staple Egyptian cotton and the Sea Island varieties. It is capable of attacking some of the Indian varieties. Fig. 32 shows a leaf of G. indicum variety grown in soil infected with the Egyptian *Fusarium*. The characteristic mosaic symptoms are very apparent. On other American cotton varieties apart from the Sea Island varieties it is a weak parasite. The author is inclined to consider the Egyptian *Fusarium* of cotton as distinct from the American and the Indian.

The work carried out shows clearly that the differences lie in the following points :—

(1) The morphology of the chlamydospores.
(2) The substratum colouration and cultural characters.
(3) The parasitism.

The author therefore suggests calling this fungus, at any rate until further studies are carried out, *Fusarium vasinfectum var. Egyptiacum.*

Moreover the Egyptian *Fusarium* occurs in Egypt in the heavier types of soil, while *Fusarium vesinfectum* is reported by Gilbert [16] as rarely occurring on clay, being most severe on sandy soil where Heterodera radicicola is very frequently present.

Dr. W. A. Orton in a letter dated the 26/12/1923 addressed to Mr. Baily, ex-Director of the Botanical Section of this Ministry, writes:—

" In this country (U.S.A.) the *Fusarium* Wilt has not spread into the heavier soils of the South nor into the irrigated regions. "

TABLE 28.—SHOWING THE SUSCEPTIBILITY OF THE EGYPTIAN COTTON VARIETIES TO THE EGYPTIAN FUSARIUM, FUSARIUM VASINFECTUM AND THE INDIAN FUSARIUM.

(Average result of two years).

Variety of Cotton.	Determination of Species.	*Fusarium* Egyptian.			*Fusarium vasinfectum*			*Fusarium* Indian.		
		Total.	Diseased.	Percentage of Diseased.	Total.	Diseased.	Percentage of Diseased.	Total.	Diseased.	Percentage of Diseased.
		Plants.			Plants.			Plants.		
Sakel	G. peruvianum cav. var.	85	54	63·5	53	5	9·4	49	0	0
Ball's 310	G. barbadense Linn × peruvianum cav. both nearer to the other ...	56	40	71·4	38	3	7·8	32	0	0
Pilion	G. peruvianum cav. var.	81	13	16	52	2	3·8	45	0	0
Assili	G. peruvianum cav. var.	66	20	30·3	61	3	4·9	47	0	0
Abbassi	G. peruvianum cav. var.	40	6	15	53	0	0	43	0	0
Nubari	G. peruvianum cav. var.	45	19	42·2	53	2	3·7	40	0	0
Dom. Joannovitch	G. peruvianum × vitifolium Lamk...	35	4	11·4	58	3	5·1	53	0	0
WhiteJoannovitch	G. peruvianum × vitifolium Lamk...	57	14	24·5	44	4	9	47	0	0

TABLE 28 (*contd.*).

Variety of Cotton.	Determination of Species.	*Fusarium* Egyptian.			*Fusarium vasinfectum.*			*Fusarium* Indian.		
		Total.	Diseased.	Percentage of Diseased.	Total.	Diseased.	Percentage of Diseased.	Total.	Diseased.	Percentage of Diseased.
		Plants.			Plants.			Plants.		
Casuli	G. barbadense Linn × peruvianum cav. ...	63	6	9·5	70	3	4·2	54	0	0
Toudri	G. peruvianum × vitifolium Lamk...	46	7	15·2	43	4	9·3	40	0	0
Fathi	G. peruvianum cav. × vitifolium	48	9	18·7	39	1	2·5	43	0	0
Ball's 77	G. Barbadense × brasilense Macf	29	2	6·8	46	1	2·1	54	0	0
Zagora...	G. peruvianum × vitifolium Lamk...	94	0	0	55	2	3·6	40	0	0
Ashmouni	G. peruvianum × vitifolium Lamk...	88	0	0	63	1	1·5	63	0	0
Ball's 111	G. peruvianum × vitifolium Lamk...	25	2	8	51	1	1·9	48	0	0

TABLE 29.— SHOWING THE SUSCEPTIBILITY OF THE SEA ISLAND COTTON VARIETIES TO THE EGYPTIAN FUSARIUM, FUSARIUM VASINFECTUM AND THE INDIAN FUSARIUM.

(Average result of two years).

Variety of Cotton.	Determination of Species.	*Fusarium* Egyptian.			*Fusarium vasinfectum.*			*Fusarium* Indian.		
		Total.	Diseased.	Percentage of Diseased.	Total.	Diseased.	Percentage of Diseased.	Total.	Diseased.	Percentage of Diseased.
		Plants.			Plants.			Plants.		
Harland's	—	26	12	46·1	38	1	2·6	42	0	0
Mont Serrat ...	G. barbadense Linn. var. maritimum Watt ...	37	20	54	22	1	4·5	38	0	0
A. B. 42	G. barbadense Linn. var. maritimum Watt ...	31	9	29	38	0	0	35	0	0
A. N. 28	G. barbadense Linn. var. maritimum Watt ...	36	22	61·1	33	1	3	54	0	0
St. Kitts	G. barbadense Linn var.	49	17	34·6	48	0	0	51	0	0
Superfine	—	40	17	42·5	28	0	0	45	0	0
St. Vincent ...	—	9	5	55·5	28	1	3·5	8	0	0

TABLE 29 (*continued*).—SHOWING THE SUSCEPTIBILITY OF THE AMERICAN COTTON VARIETIES TO THE EGYPTIAN FUSARIUM, FUSARIUM VASINFECTUM AND THE INDIAN FUSARIUM.

(Average result of two years).

Variety of Cotton.	Determination of Species.	*Fusarium* Egyptian.			*Fusarium vasinfectum.*			*Fusarium* Indian.		
		Total.	Diseased.	Percentage of Diseased.	Total.	Diseased.	Percentage of Diseased.	Total.	Diseased.	Percentage of Diseased.
		Plants.			Plants.			Plants.		
Webber (Cockēr's strain)	—	42	3	7·1	45	1	2·2	52	0	0
Councilor-Tool ...	—	38	6	15·7	43	3	6·9	48	0	0
Dixie-Trumph ...	G. hirsutum Linn × mexicanum Tod. nr. mexicanum	64	2	3·1	58	5	8·6	42	0	0
Triumph	G. hirsutum Linn × mexicanum Tod. nr. mexicanum	37	1	2·7	31	0	0	49	0	0
Express 95 ...	G. hirsutumn Lin × mexicanum Tod. nr. mexicanum	57	1	1·7	33	3	9	60	0	0
Express	G. hirsutum Linn × mexicanum Tod. nr. mexicanum	50	0	0	37	5	13·5	55	0	0
Lone Star	G. hirsutum Linn × mexicanum Tod. nr. mexicanum	35	2	5·7	33	0	0	39	0	0

Foster 11	G. hirsutum Linn × mexicanum Tod. nr. mexicanum	42	0	0	37	1	2·7	43	0	0
Truit from Ellis.	G. hirsutum Linn × mexicanum Tod. nr. mexicanum	51	1	1·9	29	5	17·2	52	0	0
Rowden	G. hirsutum Linn × mexicanum Tod. nr. mexicanum	42	3	7·1	33	0	0	57	0	0
Dixie	—	62	0	0	42	1	2·3	51	0	0
Clemson clair ...	—	60	3	5	54	2	3·7	68	0	0
King wood	—	43	6	13	36	2	5·5	63	0	0
Trise	—	57	5	8·7	56	0	0	63	0	0
Cooker's webber	G. hirsutum × vitifolium lamk	53	1	1·8	44	0	0	68	0	0
Cook	—	61	3	4·9	49	6	12·2	58	0	0
Toole	—	62	2	3	69	1	1·4	84	0	0
Willow leaf ...	—	40	0	0	25	7	28	47	0	0
Red leaf	G. Mexicanum Tod ...	27	5	18	37	0	0	45	0	0
American king ...	G. hirsutum Linn... ...	32	0	0	42	3	7·1	46	0	0

TABLE 30.—SHOWING THE SUSCEPTIBILITY OF THE INDIAN COTTON VARIETIES TO THE EGYPTIAN FUSARIUM, FUSARIUM VASINFECTUM AND THE INDIAN FUSARIUM.

(Average result of two years).

Variety of Cotton.	Determination of Species.	*Fusarium* Egyptian.			*Fusarium vasinfectum*			*Fusarium* Indian.		
		Total.	Diseased.	Percentage of Diseased.	Total.	Diseased.	Percentage of Diseased.	Total.	Diseased.	Percentage of Diseased.
		Plants.			Plants.			Plants.		
G. indicum C.P.	G. Nanking Meyen var. Bani Watt	37	4	10·8	48	0	0	14	2	14·2
K. 22 (U.P.) ...	G. arborium Linn. var neglectum	69	6	8·6	42	0	0	32	5	15·6
G. Neglectum ...	G. arboreum Linn. var. neglectum watt ...	50	4	8	35	0	0	26	18	69·2
G. Roseum... ...	G. arboreum Linn. var. rosea Watt Recessive X	54	1	1·8	69	0	0	31	1	3·2
G. Malvensis ...	G. Nanking var. rubicunda Watt	45	1	2·2	50	0	0	53	0	0
G. obtusifolium.	G. obtusifolium var. hirsutior	48	14	29·1	48	0	0	60	0	0
G. Nanking Mayen		53	13	24·5	66	0	0	79	0	0

PART III.—THE CONTROL OF THE DISEASE.

The study of the control of this disease was divided into three parts.

(1) The effect of barefallow on infective soil.

(2) The disinfecting capacity of carbon bisulphide.

(3) The selection of resistant long staple cotton (Sakel).

(1) The effect of Barefallow.

Though barefallow was already known from actual observations to be of little or no value as a control for this disease the following experiment was however carried out under laboratory conditions.

Four wooden tubs 80 cm. in diameter by 70 cm. deep were filled with soil (dry Nile mud). Of these, two tubs received parasitic culture of the Egyptian Cotton *Fusarium* while the other two were not infected, being left as control. The four tubs were sown in March 1923 with Sakel cotton known to be susceptible. Twenty days after sowing the cotton seedlings were pulled up and examined. Those growing in the infected tubs were found discoloured at their central cylinder and gave a pure culture of *Fusarium* on isolation, while the seedlings growing in the control soil were free from any discoloration and attempts to isolate the parasite from these seedlings failed. The *Fusarium* isolated from the plants growing in the infected tubs proved parasitic on being re-tested on Sakel cotton. In this way it was absolutely certain that soil in the two tubs which had received the cultures was infective.

The four tubs were left barefallow for a year. At the same period as that of the first sowing, they were sown again with the same variety of cotton namely Sakel. The tubs which had received the *Fusarium* culture a year previous to this second sowing, again produced diseased plants which on isolation gave a pure culture of *Fusarium*; which again proved to be parasitic on Sakel cotton while those growing in the uninfected or control tubs gave healthy plants. During the whole period of the experiment the four tubs were left in the open. No water was added to the soil of the tubs during the barefallow period which lasted as stated above for a year. The rainfall during that period, April 1923 to April 1924, at Giza where the experiment was carried out is shown in table 31.

A similar experiment was carried out using naturally infected soil from plot No. 26 Gemaiza, instead of artificially infected Nile mud as in the above experiment.

The results of the two experiments were identical.

TABLE 31.—SHOWING THE MONTHLY TOTAL RAINFALL (mm.) GIZA (COTTON RESEARCH BOARD) FROM APRIL 1923 TO APRIL 1924.

Year.	Month.	Rainfall (mm.)
1923	April	0·0
	May	16·4
	June	0·0
	July	0·0
	August	0·0
	September	Drops.
	October	25·9
	November	1·7
	December	5·6
1924	January	5·0
	February	Drops.
	March	18·0
	April	0·0

(2) THE DISINFECTING CAPACITY OF CARBON BISULPHIDE (CS_2)

Four wooden tubs of the same capacity as those used in the test mentioned above were filled with soil (Nile mud) and artificially infected and tested as in the case of the barefallow experiment. Two tubs were treated with carbon bisulphide as described below, using the Vermorel injector, Pal Exelsior. The amount of carbon bisulphide used was at the rate of 100 c.c. per square meter, 30 cm. deep. After the treatment the tubs were watered to prevent the escape of CS_2 gas.

Three weeks later the treated and the untreated tubs were sown with Sakel cotton. In the treated tubs no cotton seed grew in spite of the repeated resowings while the control tubs produced diseased plants.

The treated tubs had finally to be left unsown. A year later the two treated and the two untreated were again sown with Sakel cotton. The treated tubs produced healthy plants while the untreated produced again diseased plants.

The results of this experiment are of little value. The dose is undoubtedly too high. It is however capable of destroying the parasite within the soil, under the conditions described above.

Field trials are being carried out to test the value of smaller doses at different depths. The results will be published later.

The author has some doubt as to the value of CS_2, as a soil disinfectant under field conditions against this disease, because of

the presence of the fungus in the deep layers of the soil, one meter and perhaps more (*see* table 18) and because of the high cost of this disinfectant. It is indeed, very doubtful if any soil disinfectant will be of much use in this country.

(3) The Selection of Resistant Strains of Sakel Cotton.

This part of the work has been given the greatest attention. The method used and the results obtained are given below at some length.

In 1923 tha author made a tour in Lower Egypt with the object of selecting apparently resistant Sakel cotton plants from infected fields grown with Domains Sakel seed. The worst infected localities were visited and the most infected fields were chosen. The selection was done only from fields grown with Domains Sakel rather than from those grown with commercial Sakel, which contains a high percentage of impurities. Domains Sakel, though highly susceptible was preferred because of its excellent lint quality.

The following table gives the names of the localities and the number of farms and fields from which the selection was made, also the number of the selected plants.

Table 32.—Showing the Names of the Localities and Number of Farms, Fields and Plants selected.

Province.	Localities.		Farms.	Number of Fields.	Plants
	District.	Village.			
Daqahlîya	Aga	Sahragt el Soghra...	1	2	49
,, ...	,, ...	Kafr Diarb.	1	1	15
,, ...	,, ...	Sangid ...	1	1	7
,, ...	,, ...	Shannîsa ...	1	1	32
Menûfîya	Tala... ...	Bimam ...	1	1	9
,, ...	,, ...	El Benda-rîya ...	1	1	29
Total 2	2	6	6	7	141

The Method of Selection.

From the worst infected patches cotton plants were selected from those that had survived the disease. Plants were selected only

from " holes " or " hills " which had two plants one of which was showing definite symptoms of the disease the other being perfectly healthy. Both plants were pulled out and their roots slit and examined for the characteristic discoloration of the central cylinder. The examined plants which showed no external or internal signs of the disease and which had a diseased companion plant growing in the same " hole " or " hill " were selected.

The method of selecting healthy plants growing next to diseased was preferred rather than the selection of healthy plants growing singly to insure the presence of infection at the spot where the selected plants were growing.

The diseased plants growing next to the healthy selected plants were in the majority of cases so severely infected that they had not produced a crop or only a few bolls. Generally their main stem had died and the few basal branches formed, bore a few unmatured bolls and sometimes flowers.

The selected plants were picked separately in small calico bags. They were then brought to the laboratoy at Giza where the seed cotton of each plant was ginned separately.

The author was well aware of the heterozygous nature of the majority of selected plants. He was also aware of the fact that some of the selected plants though they showed no sign of the disease, might in spite of growing next to an infected plant, have escaped infection. It was therefore necessary to grow these selected plants by the plant-to-row method in infected soil to further select the desirable types which would resist infection.

The 1924 Test.

At this period of the investigation it was thought that to expose a plant to infection it would be sufficient to add a parasitic culture of the Egyptian *Fusarium*, with the seed at sowing time.

The cultures of the fungus isolated from diseased cotton plants obtained from Kafr El Zayat, Tanta, Mit Ghamr, Kom Hamada and Tala, which had proved to be parasitic on Sakel cotton growing in pots as shown in table 7 were subcultured on acid potato plug. (M. 3). When growth was complete after 10 days incubation at 30° C an equal number of the different cultures was broken up together in a known amount of water. A definite amount per hole of this culture suspension containing the culture content of a culture tube (18 cm. × 18 mm.) was poured on the seed at sowing.

Besides the seed of the selected plants, seeds of the Botanical Section Sakel AA/23, B/23, C/23, and D/23 known to be susceptible to this disease were also similarly sown in the mycological plot. This was done to check the infecting capacity of culture suspension when

placed with the seed at sowing; and also with the hope of finding resistant plants among these Sakel varieties.

Thirty-five days after sowing all seedlings except one per hole were pulled out and examined for the discoloration of the central cylinder and isolations made of the discoloured roots. The result of this examination, *i.e.*, the number of seedlings discoloured in the central cylinder which gave a *Fusarium* on isolation, was recorded for each family.

The Sakel varieties obtained from the Botanical Section and sown as a check were those that gave the highest percentage of seedling infection; a few of these showed also the mosaic symptoms. Some of the selected plants showed a high percentage of seedling infection, while others showed definite signs of resistance. All plants were kept under observation until maturity. Of the families, which showed a high percentage of purity to one type and resistance a number was selected; of these the best plants were marked. The marked plants were described and selfed. At maturity the seed-cotton of each plant was picked separately, the seed-cotton of selfed bolls being kept separate from that of the unselfed or natural bolls.

All plants whether of the selected or unselected families were then pulled up and examined for the presence of the discoloration in the central cylinder of their roots. Those showing the slightest discoloration whether typical or not were considered as diseased.

Contrary to what was expected only very few plants, and the majority of these from the Botanical Section Sakel varieties showed the characteristic dark olive streaky discoloration, Fig 10. Many plants, however, and many of these of the selected families showed a peculiar localised discoloration in the hypocotyl region similar to that occurring in some Ashmouni plants referred to before as " Upper-Egypt " discoloration in part I of this bulletin. Fig. 28 gives a number of slit roots of these plants showing this " Upper-Egypt " discoloration. On the right hand side of the photograph four typically discoloured roots and on the left hand side one healthy root are given for comparison. All these roots as shown in Fig. 28 are of plants grown in the 1924 resistance test.

On isolation, the limited discoloured portion (Upper-Egypt discoloration) of the above-mentioned plants gave a culture of *Fusarium* which when tested proved parasitic on Sakel cotton grown in pots.

A striking fact was that many plants of the Botanical Sakel varieties known to be susceptible when grown in infected pots, showed this Upper-Egypt discoloration when grown in the mycological plot in 1924.

The limited discoloration was suggested in appearance of that produced through wound infection in resistant cotton as described in part I of this bulletin, Fig. 23.

No trace, however, of external injury on the roots could suggest a wound through which the parasite could have gained entrance. In many cases, there was a slight swelling at the hypocotyl where this discoloration was present within the tissue. No cavity however, similar to that produced in the plants hypodermically injected was observed. In other words the plants showing this limited discoloration were simply locally infected.

The result of the 1924 infection test may be summarised as follows :—

(1) Many plants at the seedling stage showed definite signs of the disease, principally a discoloration which gave in the majority of cases a parasitic *Fusarium* on isolation.

(2) Many adult plants showed the limited discoloration described above as " Upper-Egypt " discoloration, and which gave a parasitic *Fusarium* on isolation.

(3) Few adult plants showed typical discoloration.

Many plants seem to have got infected at the seedling stage but as they grew they were able to put a stop to the spread of infection by localising the parasite in the hypocotyl.

This matter requires explanation :—

It has been mentioned above that the method employed for infection in 1924 was by placing a suspension of parasitic culture with the seed at sowing. In this method only the upper few centimetres of surface soil were infected with the parasite, underneath this infected layer the soil was practically free, at any rate during the cotton season of 1924.

The seed was sown about the middle of March. The roots of the seedlings during their early growth came in contact with the parasite, and some got infected. It seems as the plant grew and the roots penetrated the clean soil, the plant was able to grow quicker than the progress of the parasite in its tissue. The temperature at this period is more suitable for the growth of the plant than for the *Fusarium* parasite. As the plant was able to make vigorous growth it became better able to react against infection and was able to encircle the parasite in the hypocotyl by the formation of the gum-like substance within the cells in the neighbourhood of the infected zone. In this manner the progress of the parasite came to a stand-still.

If the method of infection described above is compared with that which occurs in the naturally infected fields, it will be found that in the latter case, where the parasite may exist as deeply buried in the soil at one meter and perhaps more, the roots of the plant as they grow in the soil are subjected to repeated infection, during the whole period of the growth of the plant : The possibility of repeated infection seems

to the author to be an important factor in determining the degree of the attack. In fact it is quite possible that a plant is able to withstand up to a certain number of these repeated infections, as an animal can withstand a certain number of parasitic organisms without developing the disease.

The above emphasise the fact that to expose a cotton plant to the *Fusarium* disease, it is essential to expose its root system as it grows to repeated infection. This fact was taken into consideration in the 1925 selection test.

The 1925 Test.

As explained above it then became necessary to test the cotton plants as to their resistance in a soil which would repeatedly expose the roots to infection.

A naturally infected field was first thought of, as a suitable place to grow these plants, but it soon became apparent that the patchy nature of the infected field would expose the plants to infection unevenly and it would be impossible to know with certainty whether the plants which show no disease are resistant or simply happened to be growing in a clean patch. It therefore then became necessary to find a medium which would not only expose the plant to infection but which would expose equally to infection all the plants desired to be tested. In other words it was necessary to have the soil in which each plant was to be grown, equally charged with infecting matter. To thoroughly infect a whole field up to the depth of say 50 cm. would be practically an impossible task.

The infection experiments carried out in pots had up to then given satisfactory results. To grow the selected plants in pots would not however permit the complete development of the roots and would be detrimental to their normal development. If, however, the bottom of the pot is removed, the plant would then continue its root growth, practically unaffected by the limitation of the pots on the sides. In other words a bottomless pot was required, fig. 45.

The question to settle next was the kind of the soil to be used in these bottomless pots. Naturally a soil from heavily infected field was preferred. For this reason, a heavily infected soil from Gemaiza farm (plot 26, fig. 29) (*see* the rotation experiment page 48) was chosen. This soil had been tested and found infective.

Thirty metric tons of soil were skimmed off the surface of plot No. 26 to the depth of 5 centimetres and sent to Giza.

To increase the infecting capacity of this soil the contents of 200 culture tubes (18 cm.×18 mm.) on acid potato plug were added per cubic meter. An infection experiment carried out to test the infective capacity of this infected soil showed that nearly all the Sakel cotton

plants grown in bottomless pots filled with this soil died when 10 to 20 days old.

These two questions, namely the limitating of the roots of plants to be grown in infected soil by the use of "Bottomless pots" and the choice of a soil of high infective capacity having been settled, there remained a third question, that of the depth of the infected soil to be used.

The bottomless pots as shown in fig. 45 have the following dimensions 24 × (top 14, bottom 12 cm.). Generally under natural infection the most infective layer of the soil is the 40 cm. top surface soil (*see* table 18). For safety, however, it was thought it would be best to make the infected layer for this test 50 cm. deep. Holes 40 cm. apart, 50 cm. deep, 14 cm. wide, were dug in lines 75 cm. apart. A bottomless pot was placed upright in each of these holes in such a way that the upper portion of the pot was level with the soil surface. The hole with the pot placed in it was filled with infected soil as explained later.

Fig. 46 shows the mycological plot with the bottomless pots buried in the soil.

The Infected Soil.

The Preparation of the Infected Soil.

As mentioned above it was essential to have the soil, in which it was required to test the selected plants as to their resistance, evenly and equally charged with the parasite.

The Egyptian *Fusarium* of cotton, was again isolated from diseased cotton plants obtained from the different provinces of Lower Egypt in preference to the use of subcultures of the previous year isolation. The *Fusarium* fungus of the different isolations was tested and found parasitic on Sakel cotton.

Parasitic cultures isolated from diseased cotton plants grown in 4 provinces where the disease is severe were used in preference to one strain of the parasite with the object of exposing the plants to the attack of several strains of the *Fusarium* parasite of cotton, if such exist. The question of the possible existence of different strains of the *Fusarium* in the different provinces is under study, the result of which will be published later.

Table 33 gives the names of the provinces and localities from which diseased plants were obtained for isolating the parasite.

The 30 tons of soil obtained from plot 26 at Gemaiza were divided up into 30 heaps of $\frac{3}{4}$ of a cubic meter each. To each heap one quarter of a cubic meter of well rotted farm yard manure was added, making a total volume of one cubic meter per heap. The thirty heaps were divided up into 5 lots of 6 heaps each. The 6 heaps of each lot received

Table 33.—Showing the Names of the Provinces and Localities from which the Diseased Plants were obtained for Isolating the Parasite.

Province	Locality	Remarks.
Behera...	Kom Hamada ...	
Daqahlîya	Mit Ghamr... ...	
Gharbîya	Tantâ	All proved parasitic on
„	Kafr el Zayat ...	Sakel cotton grown at
Menûfîya	Tala	Giza.

each the contents of 200 culture tubes (18 cm. × 18 mm.) of the parasite on acid potato plug (M. 3) isolated from a diseased plant of one of the localities mentioned in table 33. In other words the five lots were each infected with the parasite isolated from one of the 5 localities mentioned above. Small heaps were preferred to large heaps for the reason of the facility of better mixing the culture with the soil Fig. 47. After infection, the 30 heaps were mixed together in such a way as to evenly distribute the infected soil of the different heaps together.

The holes, where the bottomless pots were placed, were then filled with the mixed infected soil, to the depth of about 50 cm.

To test the infective capacity of the soil ordinary pots were filled with this soil and sown with Sakel Cotton. The pots were placed in a heated green house, being the month of January it was too cold to grow cotton in the open. The characteristic symptoms appeared on the plants grown in the green house after three weeks. The diseased plants were examined microscopically and were found to contain the hyphæ of the fungus whithin the water conducting vessels. Isolations were made and a *Fusarium* was obtained.

The Plants sown in 1925.

It is necessary here to mention the method followed in the 1924 final selection.

It has been mentioned above that the best plants of families pure to type which showed apparent resistance in the seedling stage had been marked and selfed during 1924. After picking, all the plants grown in the mycological plot were then pulled up and their roots examined, as has been already mentioned. Plants which showed only perfect freedom from discoloration were selected for the 1925 test.

These belonged to three groups :—

(A) Marked plants of selected families.
These produced (*a*) selfed seed and (*b*) natural or unselfed.
(B) Marked plants of unselected families.
These produced only unselfed or natural seed.
(C) Unmarked plants of unselected families.
These produced unselfed or natural seed.

Seeds of plants of group (A) and half the seeds of each plant of group (B) were sown at Giza in bottomless pots while the remaining seed of each plant of group (B) and the whole of the seed of group (C) were sown at Miniet Samanoud in a naturally infected field, the mycological plot being then too small for growing (A), (B) and (C) together.

The method of sowing followed either at Giza or Miniet Samanoud was the plant-to-row.

Sowing took place on the 13th to the 18th of March, four seeds being sown per bottomless pot at Giza and six per hole at Miniet Samanoud. Germination was poor at Giza and a month later resowing took place. At Miniet Samanoud, however, resowing was much less than at Giza. Both fields were kept under observation for the appearance of the mosaic symptoms, and two months after sowing, *i.e.*, about the middle of May the plants were thinned ; leaving one plant per bottomless pot at Giza and one per hole at Miniet Samanoud. All thinned plants were examined for the presence of the discoloration and cultures made of the discoloured ones to ascertain the presence of the *Fusarium*.

At Giza.

The disease was very apparent in some families ; in fact, in some cases all the plants had by the time of thinning entirely died out some after showing the mosaic symptoms. The resistance was found to vary greatly in the different families some showed high resistance while others proved very susceptible. The percentage of diseased thinned seedlings was calculated. According to this result families were selected which showed purity to the Sakel type and a high degree of resistance. This selection was done as the plants came into flower. Of group (A) 68 families were selected of which 238 plants were marked as of good type, of group (B) 68 families were selected and the number of marked plants was 253 making a total of 136 selected families and 491 marked plants of desired type. The marked plants were described and selfed as done in the 1924 selection.

It is just worth mentioning that in the selection of plants since 1924, plants with sympodial tendency of growth were preferred to those of monopodial habit, the idea being that those of sympodial tendency are earlier maturing than those of monopodial type, an important factor in reducing the damage done to the crop by the pink boll worm.

Botanical Section Sakel varieties as grown in 1924 ; Domains Sakel and Nahda (Selected Assili) were also sown in the mycological plot in bottomless pots as a check. The majority of the Botanical Section and Domains Sakel cotton died at the seedling stage and in spite of the repeated resowing no suitable plant was found free from the characteristic discoloration of the roots when examined at the end of the cotton season. The Nahda was more resistant in the seedling stage but again in October when the roots of the plants were examined the majority of the plants left were found typically discoloured. The Botanical and Domains Sakel and the Nahda had to be discarded that year being of no practical value as a basis for selection.

At Miniet Samanoud.

The disease was found to be less severe than at Giza and did not appear to be evenly spread in the field. As mentioned above, half the seeds sown at Miniet Samanoud was also sown at Giza in bottomless pots where the parasite was known to be present. The results of the infection at Giza showed that the progeny of some plants which appeared resistant at Miniet Samanoud were susceptible at Giza in bottomless pots. On the other hand some families at Miniet Samanoud which happened to be growing in an infective patch showed the disease in some of their plants, a result which was in accordance with the results obtained at Giza. For the above reasons the infection test carried out at Miniet Samanoud could not be relied upon except in the case where the progeny of the same plants showed resistance at Giza, and this again with certain reservations.

The selected families at Miniet Samanoud were of group (B), 52 families of which 106 plants were marked, of group (C) there were 96 families of which 544 plants were marked. By taking a large number of apparently suitable plants at Miniet Samanoud it was hoped that suitable types would be obtained for future selection at Giza.

The Final Selection of 1925 at Giza and Miniet Samanoud.

At the maturity of the crop, all plants whether selfed or not were picked separately in small calico bags attached to the wand bearing the number of the marked plant, the plants were pulled up and their roots slit and examined for the presence of discoloration.

The marked plants which showed perfect freedom from discoloration were selected, all the others being discarded. In this test many more plants were found typically discoloured at Giza than in the 1924 test. There were, however, some plants which showed the limited discoloration previously mentioned in this bulletin as " Upper-Egypt " discoloration.

The few Sakel and Nahda cotton plants that remained alive to maturity were all found with a very few exceptions in the case of

Nahda, typically discoloured. Those of the Nahda variety which were not typically discoloured all showed a local discoloration.

The plants which showed the limited discoloration gave a *Fusarium* which proved parasitic on Sakel cotton, all such plants were considered in the final estimation of resistance as diseased.

There seems to be a relation between the type of discoloration, *i.e.*, characteristic or local and the degree of resistance when plants are grown for comparison in equally infected soil. Some plants appear to be semi-resistant : able to check the spread of the parasite when grown in heavily infected soil, while others are unable to stop the spread of the parasite and hence become typically discoloured.

As already mentioned, at Miniet Samanoud, healthy plants of families highly resistant at Giza were selected.

The infection-test having been satifactory at Giza in 1925 it was necessary before proceeding any further to have the lint of the selected plants graded as to its commercial value.

Mr. Charles Ross of the British Egyptian Cotton Company, Alexandria, and official grader of the Cotton Research Board, Ministry of Agriculture, graded the lint of the finally selected resistant plants. The lint submitted belonged to 179 selected plants, these were from 68 families.

Out of the lint of the 179 plants he selected 21 from 18 families which he considered as of good Sakel lint and 79 from 52 families which he passed as fair Sakel.

THE 1926 TEST.

The majority of the twenty-one good Sakel and the 79 fair Sakel plants had selfed and natural seeds.

The seed of the selected plants was as follows :—

Selfed seed of good Sakel type sown in 1926 under Experiment No. 81.

Natural seed of good Sakel type sown in 1926 under Experiment No. 82.

Selfed seed of fair Sakel type sown in 1926 under Experiment No. 83.

Natural seed of fair Sakel type sown in 1926 under Experiment No. 84.

The number of bottomless pots had been increased to 15,000 and fresh quantities of soil from plot No. 26 at Gemaiza were brought to Giza and similarly infected as was done for the 1925 test.

Of the selfed and natural seed of Good Sakel type (Exp. 81 and 82) two seeds were sown per bottomless pot together with about 8 seeds of Bamia (Okra) Hibiscus esculentus as nurse plants to assist the two

cotton seedlings to come up. Four seeds together with about 6 seeds of bamia (Okra) were sown in the other experiments, *i.e.*, 83 and 84.

To ensure the maximum germination at this time of the year, the 9th of March, the following method of sowing was carried out :—

The field where the bottomless pots were buried was watered 10 days previous to sowing. Forty-eight hours before sowing the cotton and okra seeds were soaked in water. At sowing the surface soil of each bottomless pot was hoed, and in a hole 2 cm. deep the soaked cotton and okra seeds were sown together. The seeds were covered with a thin layer of damp soil which was gently pressed over them. Over this thin-pressed damp layer of soil another layer of earth was loosely put to cover lightly the surface of the pot. Thus the previously soaked seeds were under good germinating conditions.

In spite of the exceptional cold spell which occurred at this period (March 1926) the majority of seedlings came up, no resowing was done.

The resowing of selected plants was found during the previous year to have certain disadvantages. The chief being that it was difficult at the time of selection to compare resown plants with others which had been sown a month or more previously. Also the seedlings of the resown plants had not been exposed to the same conditions as those sown a month previously, for example in March, weather conditions are known to be more suitable for the sore-shin attack, a factor which may be of value in eliminating weak seedlings. Sixty to seventy per cent of the seeds sown germinated satisfactorily. The seedlings were thinned 45 days after sowing, the thinned plants were examined for discoloration, and cultures made of the discoloured ones to determine the presence or absence of the parasite.

The same method of selection was followed in 1926 as in 1925.

At flowering time certain families were discarded being vegetatively off-Sakel-type.

The number of these families were :—

One from Experiment 81	...	Lint of mother plants
Four from Experiment 82	...	graded as good Sakel.
Eleven from Experiment 83	...	Lint of mother plants
Thirty-nine from Experiment 84		graded as fair Sakel.

The plants of the remaining families were described and selfed. When ripe the seed cotton of each selected resistant plant was picked, ginned and submitted to Mr. Ross for grading.

The most promising families were selected, the history of each is given below.

These will be propagated as described in the following pages.

HISTORY OF THE SELECTED STRAINS.

STRAIN *A*.

Plant 83→64/24–137→203/25–1169 { 1/26=A_1 ; 14/26=A_2

Variety.—Domains Sakel, grown at Sakha up to 1922.

1923 Selection.—Plant No. 83 was selected from a heavily infected field at Kafr Diarb, Aga, Daqahlîya Province.

1924 Selection.—The progeny (Natural seed) of this plant was grown under No. 64/24. Seven per cent of the plants produced (seedlings and adult plants) were found locally (not typically) discoloured at the hypocotyl region. From among the healthy plants, plant No. 137 was selected.

1925 Selection.—The progeny (Natural seed) of plant No. 137 was grown under No. 203/25. None was found diseased. Plant No. 1169 was selected, its lint being graded as good Sakel.

1926 Selection.—The progeny of plant 1169 was grown under No. 1/26 for the selfed seed (A_1), and under No. 14/26 for the natural seed (A_2). Of these grown under No. 1/26 none was found diseased, while of those grown under No. 14/26 one seedling and one adult plant were found very slightly (not typically) discoloured.

Considering that these are diseased, the percentage of infection in No. 14/26 would be 1·7

The lint was graded by Mr. Ross, the results are given in table 34.

THE DESCRIPTION OF STRAIN *A*.

The families and plants mentioned above were described in 1924, 1925 and 1926, and were found to have remained pure to one type since 1924. The following is the description:—

Habit: Sympodial, Stem: erect, with many fruitful sympodia of medium length, leaves: of medium size inflexed deeply cut with a faint pulvinus, flowers: yellow decidedly larger than bracts with a diffused spot, bolls: Sakel type, lint: Sakel.

N.B.—It is interesting to note that in the case of No. 14/26 the seed used was natural and it is quite possible that the plants considered diseased were offsprings due to cross pollination with a susceptible parent.

STRAIN *B*.

Plant. 83→64/24–141→128/25–215 { 3/26=B_1. ; 17/26=B_2.

Variety.—Same as strain *A*.

1924 Selection.—Same as strain *A* except that the plant selected at the end of the season was No. 141.

1925 Selection.—The progeny of plant (natural seed) No. 141 was grown under No. 128/25, of this none was found diseased. Plant No. 215 was selected, its lint being graded as good Sakel.

1926 Selection.—The progeny of plant No. 215 was grown under No. 3/26 for the selfed seed (B_1) and under 17/26 (B_2) for the natural seed. Of No. 3/26 four seedlings and two adult plants were found very slightly (not typically) discoloured, while of 17/26 six adult plants were found similarly discoloured.

Considering that these are diseased, the percentage of infection in 3/26 would be 10 per cent and in 17/26, 6 per cent. The lint was graded by Mr. Ross, the results are given in table 34.

The Description of Strain *B*.

The families and plants mentioned above were described in 1924, 1925 and 1926, and were found to have remained pure to one type.

The description is as follows :—

Habit : Sympodial, stem : erect, with many fruitful sympodia of medium length, leaves : of medium size inflexed deeply cut with faint pulvinus, flowers : yellow decidedly larger than bracts with a diffused spot, bolls : Sakel type, lint : Sakel.

N.B.—There is no apparent difference between this and strain *A* as far as external characters.

Strain *C*.

Plant. 105→59/24–124→196/25–1126 { 2/26=C_1. / 16/26=C_2.

Variety.—As *A* and *B*.

1923 Selection.—Plant No. 105 selected from a heavily infected field at Sahragt el Soghra Aga, Daqahlîya Province.

1924 Selection.—The progeny (natural seed) of this plant was grown under No. 59/24. Fifty per cent of the plants (seedling and adult plants) were found locally (not typically) discoloured at the hypocotyl region.

From among the healthy plants plant No. 124 was selected.

1925 Selection.—The progeny (natural seed) of plant 124 was grown under No. 196/25. None was found diseased, plant No. 1126 was selected, its lint being graded as good Sakel.

1926 Selection.—The progeny of plant No. 1126 was grown under No. 2/26 for the selfed seed (C_1) and under No. 16/26 for the natural

seed (C_2). Of those grown under No. 2/26 none was found diseased while of those grown under No. 16/26 two seedlings and two adult plants were found very slightly (not typically) discoloured. Considering these as diseased the percentage of infection in No. 16/26 would be 4·9.

The lint was graded by Mr. Ross, the results are given in table 34.

The Description of Strain *C*.

The families and plants mentioned above were described in 1924, 1925 and 1926.

This description is as follows :—

Habit : Monopodial in 1924, Sympodial in 1925 and 1926. Stem : erect with long fruitful sympodia in 1925 and 1926. Leaves : large in 1924 and 1925 and of medium size in 1926, all inflexed deeply cut with faint pulvinus, flowers : yellow decidedly larger than bracts with a diffused spot, boll : Sakel type, lint : Sakel.

Strain *D*.

Plt. 16→33/24–82→124/25–1068=15/26=D.

Variety.—As *A*, *B* and *C*.

1923 Selection.—Plant No. 16 was selected from a heavily infected field at El Bendaria Tala, Menoufiya Province.

1924 Selection.—The progeny (natural seed) of this plant was grown under No. 33/24, sixty-two per cent of the plants were found locally (not typically) discoloured at the hypocotyl region. From among the healthy plants, plant No. 82 was selected.

1925 Selection.—The progeny (natural seed) of plant No. 82 was grown under No. 184/25. Four adult plants were found very slightly (not typically) discoloured. Considering these as diseased the percentage of infection would then be 28. From among the healthy plants, plant No. 1068 was selected, its lint being graded as good Sakel.

1926 Selection.—The progeny of plant No. 1068 (natural seed) was grown under No. 15/26. Two seedlings and eleven adult plants were found very slightly (not typically) discoloured. Considering these as diseased the percentage would be 19. The lint was graded by Mr. Ross, the results are given in table 34.

The Description of Strain *D*.

The families and plants were described in 1924, 1925 and 1926, and were found to have remained pure to one type since 1924.

The following is the description :—

Habit : Sympodial, stem : erect with many fruitful long sympodia, leaves : very large inflexed and deeply cut with a faint pulvinus, flowers : yellow decidedly larger than bracts with a diffused spot, boll : Sakel type, lint : Sakel.

TABLE.—34 SHOWING HISTORY OF THE SELECTED STRAINS, PERCENTAGE OF THE DISCOLOURED PLANTS, THE HALO LENGTH AND RESULTS OF THE GRADING.

Strain (1926).	History.	Strain (1927).	Percentage of Discoloured plants.			Average halo length of family (1926).	Grading 1926 (Percentage of plants).		
			1924	1925	1926		Very Good.	Good.	Fair.
A	Plt. 83→64/24–137→203/25–1169→								
	Selfed seed 1/26	A_1	7	0	0	35·1	100	—	—
	Natural seed 14/26 ...	A_2	7	0	1·7	35·2	1·8	42·1	56·1
B	Plt. 83→64/24–141→128/25–215→								
	Selfed seed 3/26	B_1	—	—	10	35	—	68·8	31·2
	Natural seed 17/26 ...	B_2	7	0	6	35·2	—	18·6	81·4
C	Plt.105→59/24-124→196/25–1126→								
	Selfed seed 2/26. ...	C_1	50	0	0	34·3	33·3	33·3	33·3
	Natural seed 16/26 ...	C_2	—	—	4·9	34·6	—	36·5	63·5
D	Plt. 16→33/24–82→184/25–1068→	—	—	—	—	—	—	—	—
	Natural seed 15/26 ...	D	62	28	19	35·3	—	20·8	79·1

No typical symptoms were observed in the plants of the progeny of the selected strains since 1924. The plants considered diseased in 1925 and 1926 showed a trace of not typically discoloured tissue which on isolation gave a *Fusarium*, these discoloured plants may be considered as semi-resistant since the ordinary Sakel becomes typically diseased when grown under the same conditions.

The most promising strains seem to be *A* and *B*.

Note.—At the end of the cotton seasons of 1925 and 1926, and after the mycological Sakel was pulled up, all the bottomless pots in the mycological plot were sown with Domains Sakel which is known to be very susceptible to this disease. The disease appeared in every bottomless pot where the majority of the seedlings died. The result shows that the soil in these pots where the selected mycological Sakel grew without developing the disease is highly infective.

The method to be followed in the propagation of the Resistant Sakel Strains.

Programme for 1927.

(1) The selfed and natural seed of each plant of the four selected strains will be grown at Giza by the plant-to-row method in bottomless pots filled with infected soil as in 1926.

(2) The 1926 method of selection will be followed; *i.e.*, percentage of disease in seedling and adult plants (if any), selection of pure families and selfing best plants.

(3) At the end of the season, from the most promising families the best plants will be picked separately, the remainder of each strain will be picked together as bulk ; after discarding the families which are not true to type or not perfectly resistant (if such exist).

(4) The lint of the selected single plants and that of the bulk of each strain will be submitted to the grader. Plants or strains considered of inferior lint quality will be discarded.

Programme for 1928.

(1) The seed of the selected single plants (of crop 1927) will be sown at Giza in bottomless pots, following the same method as in 1927.

(2) The bulk seed of the selected strains will be taken to have reached the "Pure line" stage and will be sown at Gemaiza or Sakha in an isolated field naturally infected if possible, and far enough from the cotton main crop field, to avoid possible crossing.

(3) The cotton grown at Giza will be treated as in the previous year 1927(3).

(4) The strains grown at Gemaiza or Sakha will be picked and ginned separately.

(5) The lint of the plants grown at Giza will be submitted to the grader as in the previous year 1927 (4). The lint of the strains grown at Gemaiza or Sakha will also be graded and those of good lint quality will be kept for propagation on a larger scale at Gemaiza or Sakha in the following year (1929.)

Programme for 1929.

The same operation will be repeated except that in addition a second propagation on a larger scale at Gemaiza or Sakha will be carried out.

Programme for after 1929.

The growing of the resistant plants as good Sakel, in infected soil at Giza is essential not only to keep up the resistance and quality, but to form a nucleus at Giza where enough pure seed is produced every year for the first propagation. The author is well aware of the impossibility of keeping up the resistance and the quality of this cotton once it is distributed among cultivators, as a matter of fact this is not only the case with a resistant strain, but with every pure variety of cotton. However, in the case of a resistant variety the deterioration due to crossing with even a good Sakel is more apparent owing to the susceptibility of one of the parents.

After a few years' trials the number of strains will be reduced to one or two, if necessary, while the propagation on a large scale will be continued to produce enough seed every year to supply big cultivators whose land is infected. The seed produced on this land will then be retailed to small cultivators.

The production of the resistant strains should always remain under the control of the Mycological Division.

Discussion.

The Wilt disease, which the author prefers to call "the *Fusarium* disease," because of the fact that in this country the wilt symptom is often absent in diseased plants, has appeared in this country with the development of the longer staple cottons, principally Sakel. At the time when Mosseri discovered the disease in Egypt in 1902, the cotton grown then was the Mit-Afifi which as far as the tests carried out show, is more resistant than Sakel.

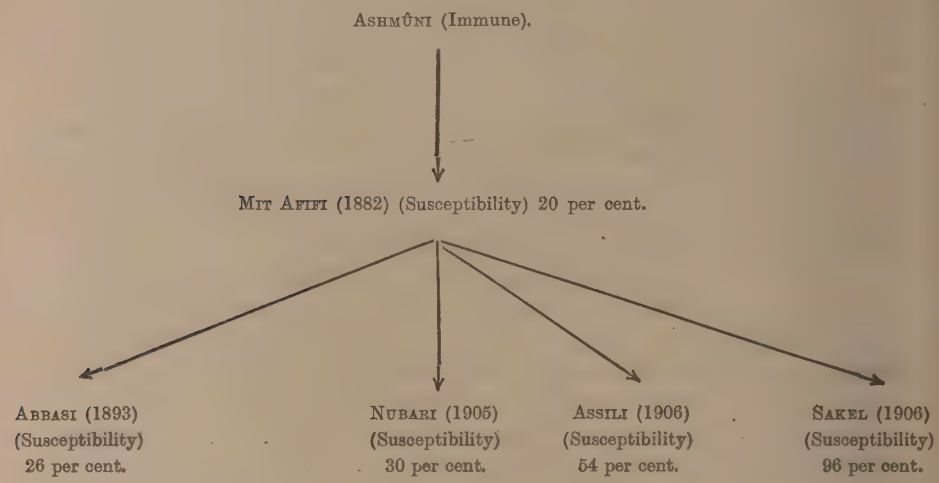
It is difficult to estimate the damage done by this disease at that period. Information collected shows that fields which are now infected were not observed as such some years previously, and that the infected patches within these fields increase in area every time a susceptible cotton is grown.

The parasite causing this disease is a soil fungus capable of active saprophytic life, most probably having always existed in Egyptian soil, and has appeared as a parasite simultaneously with the development of the plants which it was able to attack.

Ashmouni cotton, the origin of which is unknown, is resistant; Mit-Afifi is supposed to have been selected from an Ashmouni field in about 1882, the susceptibility of Mit-Afifi is 20 per cent. The following varieties were selected from Mit-Afifi at different periods, these are :—

Abbassi (1893) susceptibility 26 per cent; Nubari (1905) susceptibility 30 per cent; Assili (1906–1907) susceptibility 54 per cent; Sakel (1906–1907) susceptibility 96 per cent.

For the sake of clearness they are given in the following form :—


Ashmûni (Immune).
Mit Afifi (1882) (Susceptibility) 20 per cent.
Abbasi (1893) (Susceptibility) 26 per cent.
Nubari (1905) (Susceptibility) 30 per cent.
Assili (1906) (Susceptibility) 54 per cent.
Sakel (1906) (Susceptibility) 96 per cent.

It is interesting to note that as the lint of the varieties evolved became finer and longer, the susceptibility increased.

Sea Island cotton and other American varieties are known to have been introduced into Egypt at some early period in the development of cotton growing in this country. Sea Island which is susceptible to this disease to a marked degree, has possibly introduced the susceptibility factor into the cotton varieties evolved since its introduction; hybrids between the susceptible Sea Island and the native cotton probably an Ashmouni type, being of better lint quality, were selected. These hybrids were naturally more susceptible than their Egyptian parent, quality being more demanded, the types selected were nearer to the Sea Island in lint and susceptibility.

The above is given as a simple hypothesis, the truth of which required detailed study of the Egyptian cottons and their history.

The next point to discuss is that of susceptibility ; the author thinks that susceptibility and resistance are two genetic factors in cotton and are handed down from parent to offspring not only in quality but also in degree. Sakel is very susceptible, in fact the majority of plants die at the seedling stage when grown in heavily infected soil. Casuli on the other hand is less susceptible, the infected plants that do not die at the seedling stage, when grown under identical conditions as for Sakel mentioned above, generally survive to the end of the season in spite of the presence of the characteristic discoloration in the central cylinder of the root. Some of the progeny of certain families of the selected resistant Sakel showed a very slight discoloration in 1925 and 1926 very different from that characteristic

of the susceptible Sakel, grown under the same conditions ; yet this slight discoloration gave on isolation a *Fusarium* which proved parasitic. This quality was inherited by some of the offsprings. In other families all the plants and their offsprings remained perfectly free from any trace of discoloration.

This shows that susceptibility and resistance are inherited not only in quality but also in degree.

It seems then that the capacity of the plant to react to infection varies with some inherent character. It has also been noticed that the purer the cotton the more uniform is its reaction to this disease : Commercial Sakel when tested as to its susceptibility gives varying percentages, the average of which is lower than that of the Domains Sakel, which again gives a lower percentage than that of some of the pure line Sakel of the Botanical Section of this Ministry. In fact different strains of Sakel give different results. For example strain 21/26 *B* of the Botanical Section when grown in bottomless pots showed 91·6 per cent infection while strains 17/26 and 19/26 *C* all became infected and died at the seedling stage, *i.e.*, 100 per cent susceptibility. This question is of great interest and requires much further investigation.

The parasite has been studied in the host tissue and on artificial media, little is, however, known about its life in the soil : its natural habitat. This line of study might possibly be of economic importance, and would require a thorough knowledge of the chemical, the physical and the biologic characters of Egyptian soil.

Further studies are also required to find out whether the cotton *Fusarium* parasites existing in the different localities and causing the disease are identical or not. Also further investigation is required to study the cause and nature of the limited discoloration found in Upper-Egypt on Ashmûni cotton and referred to in the previous pages as " Upper-Egypt " discoloration.

The study of the relation between host and parasite shows that during the life of the host the fungus lives within the xylem vessels and causes the death of the host, reduces its vigour or in rare cases has no apparent influence on it. It would be interesting to know the reason for these different behaviours of the host plants. Are certain plants able to withstand the toxins of the parasite more than others ? In connection with this it would also be interesting to know the reason for the inability of the parasite to invade the tissues of resistant plants or to develop poorly in certain types so called semi-resistant ; as a matter of fact the host plant requires to be studied.

The characters of the cell sap of resistant and susceptible sakel, such as the mycological resistant A/26 selected strains and the susceptible Botanical Section strains 17/26 or 19/26 *C* require to be compared as to their pH value.

The study carried out on the relation between the Egyptian, Indian and American *Fusarium* parasites of these respective countries is only a preliminary investigation. The difficulty lies in producing under the conditions of one country, the successful development of the disease occurring in another country. The cultural studies carried out show the great possibility of a new line of study in comparing diseases so far considered the same in different parts of the world.

The results obtained in the selection of resistant plants by growing the progeny of apparently resistant plants for successive years in bottomless pots filled with heavily infected soil, are very promising. The author proposes to carry out the same method of selection with some of the Botanical Section Sakel varieties which are of excellent lint quality. It is hoped to obtain resistant strains of better lint quality than those already isolated from the Domains Sakel.

The propagation of the resistant strains so far isolated or to be isolated in future, will require great care. The nucleus plants being grown under the personal control of the author, it is hoped not only to keep their resistance but to improve their lint quality. As a whole the selected strains (A, B, C, and D) have done wonderfully well considering that they have been grown at Giza for three successive years, a locality unfit for Sakel growing and where Sakel plants tend to grow vegetatively and lose temporally some of their lint quality. It may be possible, however, in the future to transfer the growing of the nucleus plants to Sakha where Sakel is at its best.

The author hopes by an adequate method or resistant seed distribution, to be able to control this disease in infected areas without depriving the cultivator of growing Sakel which is one of the leading cottons of the world.

Acknowledgments.

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Summmary.

(1) The *Fusarium* disease of Cotton (Wilt) has been found to cause considerable damage in the Delta where Sakel cotton is mostly grown.

(2) The symptoms are given and are divided into " Internal and External."

(3) The causal organism was isolated and its morphology and cultural characters studied.

(4) The relation between host and parasite and the capacity of the fungus to produce, when grown under artificial conditions, a toxic substance capable of causing seedling cotton to wilt, are given in some detail.

(5) Different varieties of cotton have been tested as to their susceptibility.

(6) The parasite is found to persist in the soil, the infective capacity of which is influenced by various factors.

(7) The Egyptian, Indian and American *Fusarium* parasites producing the wilt disease in the respective countries have been compared and found different in certain characters.

(8) The name *Fusarium vasinfectum var. Egyptiacum* is suggested for the Egyptian parasite.

(9) Methods of control are discussed. Barefallow is found useless. Soil disinfection with CS_2 is considered as impracticable and expensive.

(10) From Domains Sakel cotton which is susceptible four resistant strains of Sakel have been isolated and have been grown in heavily infected soil for two consecutive years.

(11) These strains have been graded as Sakel of good quality.

(12) The method for future propagation is given.

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APPENDIX.

Media used.

(M_1) Cotton Wool Medium.

Absorbent cotton wool is placed at the bottom of a test tube (16 cm. by 16 mm.) to the height of 2 centimetres. This cotton wool is saturated with distilled water. The tube is plugged and autoclaved at 120° C. for 20 minutes.

(M_2) Prune Agar (25:25:1000).

(*a*) Twenty-five grammes of Prunes (without stones) are cooked in 400 cc. of distilled water in a steamer at 100° C. for one hour. The water lost by evaporation is replaced. The liquid is then filtered through filter paper.

(*b*) Twenty-five grammes of Agar are first soaked for one hour in 600 cc. of distilled water; then cooked in the autoclave at 115° C. for fifteen minutes. The water lost due to evaporation is replaced. It is then filtered through cotton wool.

(*a*) and (*b*) are then thoroughly mixed together, put while hot in test tubes and autoclaved at 120° C. for 20 minutes.

(M_3) Acid Potato Plug.

Large tubers are cut into cylinders. The cylinders are then cut across diagonally and soaked for one hour in 2 per cent lactic acid.

Cotton wool is placed at the bottom of the test tube and saturated with distilled water. A piece of potato is placed in each tube which is then plugged and autoclaved at 120° C. for 20 minutes.

(M_4) Weak Richard's Solution

The composition is as follows:—

Potassium Nitrate ($K NO_3$)	10	grams.
Potassium Hydrogen Phosphate ($K H_2 P O_4$)	5	,,
Magnesium sulphate ($Mg S O_4$)	2·5	,,
Iron Chloride ($Fe Cl_3$)	20	,,
Cane Sugar ($C_{12} H_{22} O_{11}$)	50	,,
Distilled water	1,500	cc.

When in solution it is filtered, placed in flasks, and autoclaved at 120° C. for 20 minutes.

(M_5) Rice.

One gramme of rice is placed in a test tube (16 cm. × 16 mm.) with 6 cc. of distilled water. The tube is then plugged and sterilised in the steamer at 100° C. for one hour on three consecutive days.

(M_6) Potato Agar + 2 per cent Dextrose. (200 : 20 : 20 : 1000).

(*a*) Two hundred grammes of potatoes are cut in thin slices and cooked in a steamer with 400 cc. of water for one hour. The water lost by evaporation is replaced. It is then passed through cheese cloth.

(*b*) Twenty grammes of agar are soaked for one hour in 500 cc. of distilled water, then cooked in the autoclave at 115° C. for 15 minutes. The water lost by evaporation is replaced. It is then filtered through cotton wool.

(*c*) 20 grammes of dextrose are dissolved in 100 cc. of water.

(*a*), (*b*) and (*c*) are thoroughly mixed together while hot, tubed, plugged and sterilised in the steamer (100° C.) for one hour on three consecutive days.

(M_7) Potato Agar + 5% Dextrose (200 : 20 : 50 : 1000).

Similar to M_6 except that 50 grammes of dextrose are used instead of 20 grammes.

(M_8) Oatmeal Agar (100 : 20 : 1000).

One hundred grammes of oatmeal (Quaker Oats) are put in 1000cc. of distilled water in an oven at 60° C. for one hour. The water lost by evaporation is replaced. It is then passed through muslin. Twenty grammes of agar are added, left to soak for one hour and then cooked in the autoclave at 115° C. for 15 minutes ; the water lost by evaporation is again replaced. It is then filtered through cotton wool and tubed, plugged and sterilised in the autoclave at 120° C. for 20 minutes.

(M_9).

Similar to M_3 but without soaking in lactic acid solution.

Feddan = 4,200 square metres.
Kantar of Cotton (unginned) = 141 kilograms *or* 315 rotls.
Rotl ,, ,, = 447·6 grammes.

MINISTRY OF AGRICULTURE, EGYPT.

List of Publications in English issued by the Ministry.*

The following publications may be obtained, either directly, or through any bookseller, from the Government Publications Office, Ministry of Finance, (Dawawîn P.O.), Cairo.

Agricultural Journal of Egypt.

First Series.

Vol. I, 1911. Parts I and II, P.T. 2 each part.
„ II, 1912. Part I, P.T. 2, Part II, P.T. 3.
„ III, 1913. Parts I and II, P.T. 3 each part.
„ IV, 1914. Parts I and II, P.T. 3 each part.
„ V, 1915. Parts I and II, (one volume) P.T. 5.
Vols. VI to X, 1916–1920. P.T. 5 each volume.

In 1923 a new series was started monthly in Arabic only. An English edition is published once a year containing articles selected from the year's Arabic issues.

New Annual Series.

Vol. I, 1923 P.T. 5.
„ II, 1924–1925. (In the Press.)

Egyptian Agricultural Products (By Gerald C. Dudgeon).

No.
1 A. The Great Millet (*Durra Baladi* or *Durra Rafi'a* in Egypt. 1915. P.T. 3.
2 A. The Ground Nut or Earth Pea (*Fûl Sudani*) in Egypt. 1916. P.T. 2.
3 A. Gossypium Spp., Cotton (*Qotn* in Egypt). History, Development, and Botanical Relationship of Egyptian Cottons, with tables showing Areas, Yields, Prices and Distribution of the Varieties. 1917. P.T. 5.

Technical and Scientific Bulletins.

No.
— Special Bulletin:—Egyptian Commercial Cotton, by G. C. Dudgeon. (English and French). 1918.
1. Report on the First two Years' Working of the Plant Protection Law (Law No. 5 of 1913), by G. Storey. (English or French). 1916. P.T. 2.
2. The Nature of the Damage done by the Pink Boll-Worm (*Gelechia gossypiella* Saund.), by Lewis Gough. (English or French). 1916. P.T. 1.
3. Note on the Alkaloids of some Egyptian Solanaceæ, by Frank Hughes. (English or French). 1916. P.T. 1.
4. The Life History of *Gelechia gossypiella* from the Time of the Cotton, Harvest to the Time of Cotton Sowing, by Lewis Gough. 1916. P.T. 1.

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* Revised to Nov. 1926.

† P.T. 1 = 5 cents = 2½*d.* approximately.

TECHNICAL AND SCIENTIFIC BULLETINS (*continued*).

No.

5. List of Egyptian Insects in the Collection of the Ministry of Agriculture, by G. Storey. 1916. P.T. 10.
6. Note on a Machine to kill *Gelechia* Larvæ by Hot Air, and the Effects of Heat on *Gelechia* Larvæ and Cotton Seed, by Lewis Gough. 1916. P.T. 2.
7. Work in Connection with Egyptian Wheat, by G. C. Dudgeon and B. G. C. Bolland. 1916. P.T. 1.
8. Work conducted at the Experimental Farm at Gîza in connection with Great Millet and *Bersîm*, by B. G. C. Bolland. 1916. P.T. 1.
9. Work in connection with Egyptian Maize, by G. C. Dudgeon and B. G. C. Bolland. 1916. P.T. 1.
10. Some Tests of Flour made from Egyptian Wheats, by Frank Hughes. 1916. P.T. 1.
11. Simon's Hot Air Machine for the Treatment of Cotton Seed against Pink Boll-Worm, by G. Storey. 1921. P.T. 1.
12. Experiment with Flax growing at the Government Farm at Gemmeiza, by G. C. Dudgeon. 1917. P.T. 2.
13. The Rate of Increase of the Pink Boll-Worm in Green Bolls in the period July to November, 1916, by Lewis Gough. 1917. P.T. 2.
14. Machines for the Treatment of Cotton Seed against Pink Boll-Worm (*Gelechia gossypiella* Saund.), by G. Storey. 1921. P.T. 2.
15. The Rusts and Smuts of Wheat, Barley, and Oats, by H. R. Briton-Jones. 1920. P.T. 2.
16. The Present Situation with regard to the Control of the Pink Boll-Worm in Egypt, by G. Storey. 1921. P.T. 2.
17. The Hibiscus Mealy Bug, by W. J. Hall. 1921. P.T. 3.
18. The Smuts of Millet, by H. R. Briton-Jones. 1922. P.T. 3.
19. A Wound Parasite of Cotton Bolls, by H. R. Briton-Jones. 1923. P.T. 3.
20. The Fixation of Atmospheric Nitrogen, by Frank Hughes. 1922. P.T. 3.
21. Report on a Soil Survey of Zone No. 1 (Gharbîya), 1921, by Frank Hughes. 1922. P.T. 5.
22. Observations on the Coccidæ of Egypt, by W. J. Hall. 1922. P.T. 5.
23. (*Stopped.*) Subsequently published by the Société Entomologique d'Egypte. 1922, under the title: A Monograph of the Egyptian Diptera (Part I, fam. Syrphidæ), by H. C. Efflatoun.
24. On the Dispersion of the Pink Boll-Worm in Egypt, by Lewis Gough. 1922. P.T. 5.
25. The Basis of Egyptian Agriculture and its Relation to the Decline in the Average Yield per Feddân of Cotton, by E. McKenzie-Taylor and A. Chamley Burns. 1922. P.T. 5.
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29. A Short Bio-Climatic Study in the Egyptian Desert, by C. B. Williams. 1923. P.T. 5.
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TECHNICAL AND SCIENTIFIC BULLETINS (*continued*).

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34. Preliminary Note on the Soil Temperature in *Sharâqi* Land, by E. McKenzie-Taylor and A. Chamley Burns. 1924. P.T. 5.
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39. A Preliminary Note on the Loss by Boll-Worms, by Ibrahim Eff. Bishara. 1924. P.T. 5.
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57. The Effect of the *Sharâqi* Period upon the Yield of Cotton in Egypt, by E. McKenzie-Taylor. 1926. P.T. 5.

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Third Annual Report of the Cotton Research Board, 1922. P.T. 15.
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Egyptian Agricultural and Veterinary Notes.

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Analytical Key to the Flora of Egypt, by M. Tewfik Hefnawi Eff. 1922. P.T. 5.
The Method employed by the State Domains for producing and maintaining their High Standard of Sakel Cotton. 1922. P.T. 2.
Nitrate of Lime. 1922. P.T. 2.
Ageing Egyptian Cattle, by Mohammed Askar Bey. 1923. P.T. 2.
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26. Steps to combat the Cotton Boll-Worm in May, June and July.
27. Paraffin Emulsion. (English and French).
29. Sowing Vegetable Seeds in Winter.
30. The Danger of Overwatering Cotton Fields.
35. Distribution of Cotton-Seed.
37. Fumigation of Citrus Trees.
38. Pomegranate Worm.
39. The Smut Diseases.
40. Eradication of the Pink Boll-Worm.
41. Resin Wash.
43. The Use of Nitrate of Soda in Maize Cultivation.
44. Lime and Sulphur Wash. (English and French).
46. Eradication of Fig Scale.
49. Planting Fruit Trees.
51. Planting Instructions.
52. Method of Distinguishing the Eggs, Larvæ and Pupæ of the Cotton Worm (Arabic : *Dûd el Qutn*), *Prodenia litura* F. ; the Small Green Leaf Worm (Arabic : *El Dûd el Akhdar el saghîr*); *Laphygma exigua*, Hb.; and the Greasy Cut-worm (Arabic : *Dûd el Bersîm*), *Agrotis ypsilon* Rott.
53. Destruction of Aphis.
54. Bordeaux Mixture. (French).
55. Advice on the Destruction of Boll-Worm.
61. The Seed Worm in Winter.
62. The Method of Destroying Cut-worm.
63. Instructions *re* Destruction of Locusts.
66. The Melon and Water Melon Aphis.
67. Planting Fruit Gardens.
69. Wheat Disease : Eel-worm (*Tylenchus tritici*, Baner).
71. Nitrate Experiments on *Nîli* Maize.
72. Destruction of Bolls remaining on Cotton Plants after the Last Picking.
73. Fumigation of Citrus Trees.
74. Precautions for Sowing Wheat.
75. Danger to Canals through the Spread of the Water Hyacinth.
76. Precautions for Cultivation of Beans.
77. Hay and Hay-Making in Egypt.
78. Precautions for Sowing Wheat.
80. Aphis on Cotton Trees and its Treatment.
81. Nitrate Experiments on *Nili* Maize.

AGRICULTURAL CIRCULARS (*continued*).

No.
82. Circular and Arrêté *re* fixing Date for picking and destroying of Cotton Bolls.
83. Improvement of Egyptian Wheat.
84. Protection of Insectivorous Birds. (English and French).
85. Flour Paste and Cyllin Solution.
87. Fumigation of Orange Trees.
89. For Improvement of Wheat Cultivation.
91. The Sugar-Cane Mealy Bug.
92. Measures against the Hibiscus Mealy Bug.
93. Protection of Insectivorous Birds.
96. Paraffin Emulsion (This circular cancels circular No. 27).
97. Pomegranate Fruit Butterfly, Virachola Livia Klug. (This circular cancels circular No. 38).
98. Eradication of Fig Scale. (This circular cancels circulars No. 44 and 46).
99. Bordeaux Mixture (1–1–100). (This circular cancels circulars No. 54).

COLLECTION OF AGRICULTURAL CIRCULARS.

Nos. 1–18 (1911) ; Nos. 19–35 (1912) ; Nos. 36–60 (1913–1914). Three volumes P.T. 1 each.

FIG. 1.—A cotyledon of a diseased Sakel Cotton seedling, showing the mosaic-like symptom starting from one side of the leaf.

FIG. 2.—A young leaf of diseased Sakel Cotton plant, showing the mosaic-like symptom starting from the base of the leaf.

FIG. 2*a*.—An enlarged photograph of part of the lower portion of Fig. 2.

FIG. 3.—A young leaf of a diseased Sakel Cotton plant, showing the mosaic-like symptom after it has spread all over the leaf.

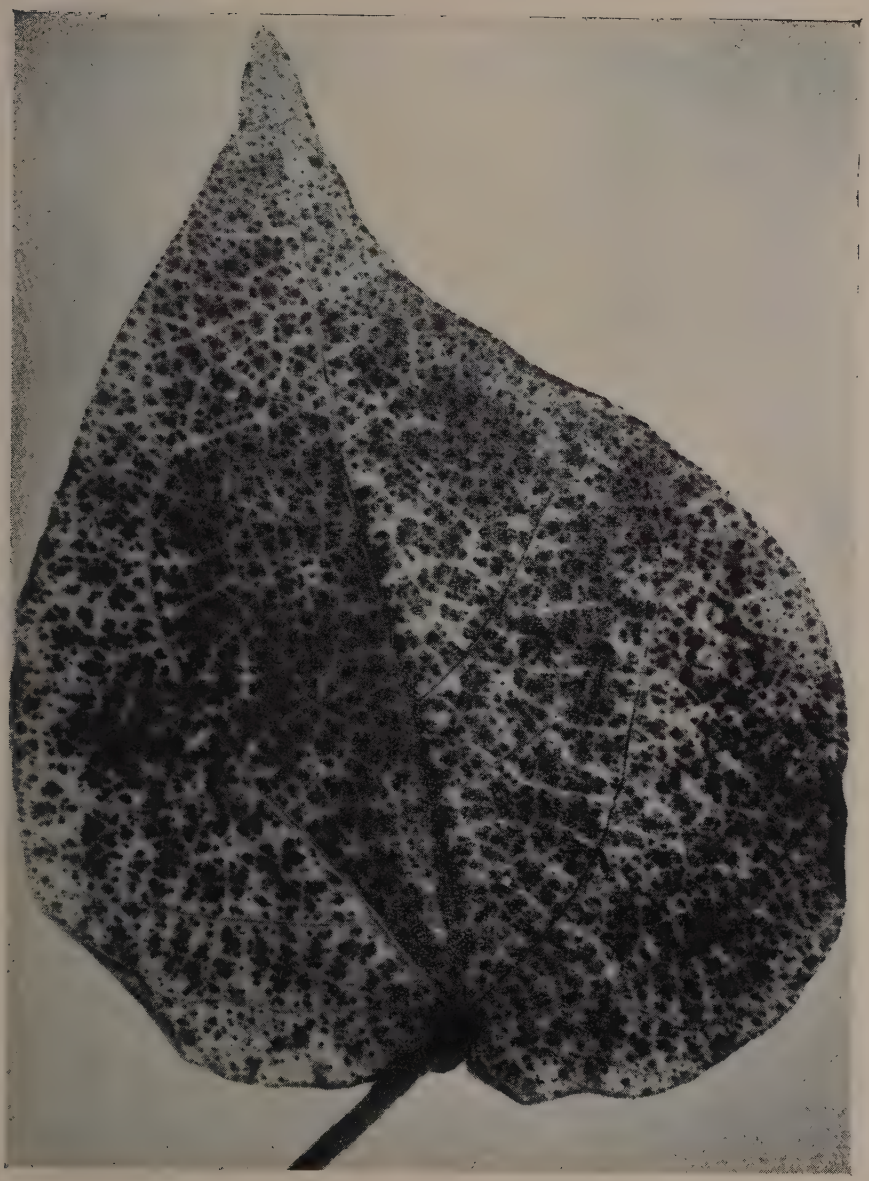


Fig. 4.—An enlarged photograph of Fig. 3, × 9 (approx.).

FIG. 5.—Diseased Sakel Cotton plants, showing death of growing points and mosaic-like symptom on an adult leaf.

FIG. 5a.—A Sakel Cotton plant, showing a kind of wilt due to physiological causes.

FIG. 6.—A diseased Sakel plant, showing abnormal formation of monopodia and death of the growing point.

FIG. 7.—A diseased Sakel plant, showing abnormal branching.

FIG. 8.—A diseased Sakel plant, showing abnormal branching.

FIG. 9.—A diseased Sakel plant, showing abnormal formation of monopodia.

FIG. 10.—A root of a diseased Sakel Cotton plant, showing the characteristic discoloration. Note the "bundles of streaks" (Mag. about 2).

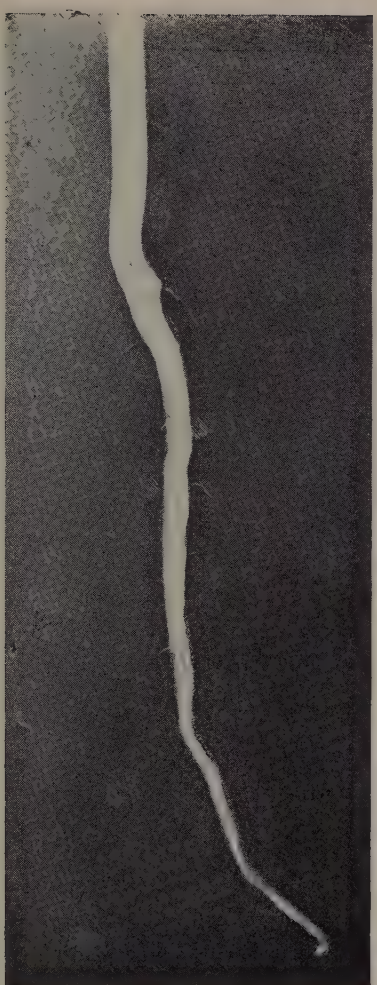


Fig. 11.—A root of a diseased Sakel Cotton plant, showing a discoloration limited to the central portion of the cylinder of the root. (This is not so characteristic as that shown in Fig. 10).

FIG. 12.—A diseased Sakel Cotton seedling, showing a light brown discoloration at central cylinder of the root.

FIG. 13.—Roots of *Ashmúni* cotton plants, showing the "Upper Egypt" discoloration.

FIG. 14.—A hypocotyl region of a diseased Sakel Cotton plant (natural infection), showing a depression in the cortical layers.

Fig. 15.—A camera Lucida sketch of a diseased Sakel Cotton root, showing the presence of hyphæ within the xylem vessels and gum-like substance formation, ×288.

(*M. Mamoun Abd el Salam* Delt.)

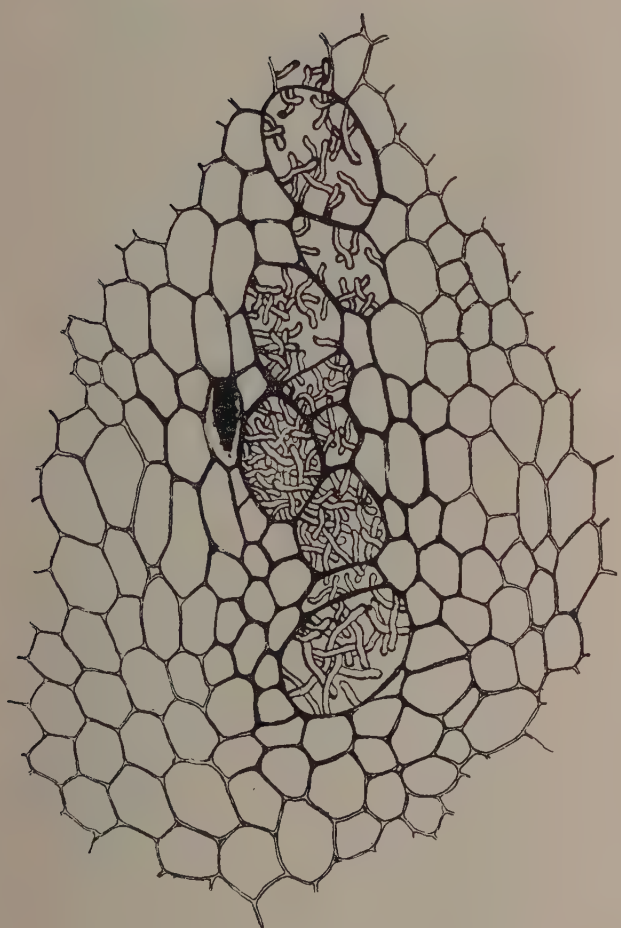


FIG. 16.—A camera Lucida sketch of a portion of a diseased Sakel Cotton root, showing the presence of hyphæ within the xylem vessels. (About × 288.)

(*M. Mamoun Abd el Salam* Delt.).

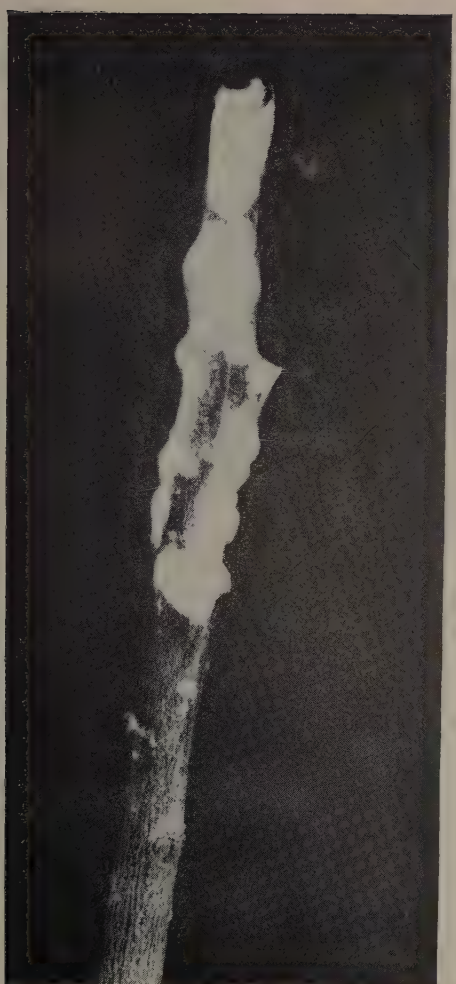


FIG. 17.—Part of a diseased Sakel Cotton plant kept under moist conditions, showing the growth of the *Fusarium* parasite.

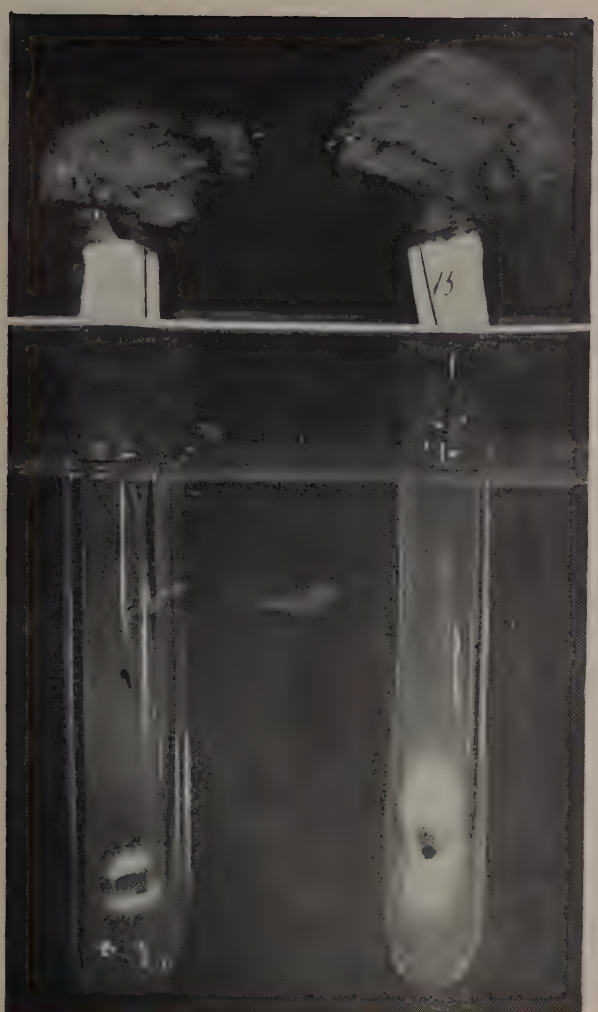


Fig. 18.—Two prune agar culture tubes with pieces of a root of a diseased Sakel Cotton plant, showing the growth of the parasite.

Fig. 19.—A culture tube of the Egyptian *Fusarium* parasite growing on acid potato plug. (M_2).

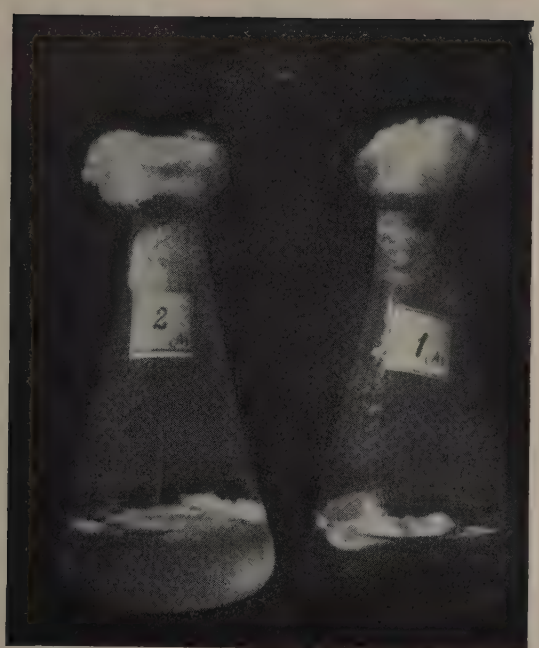
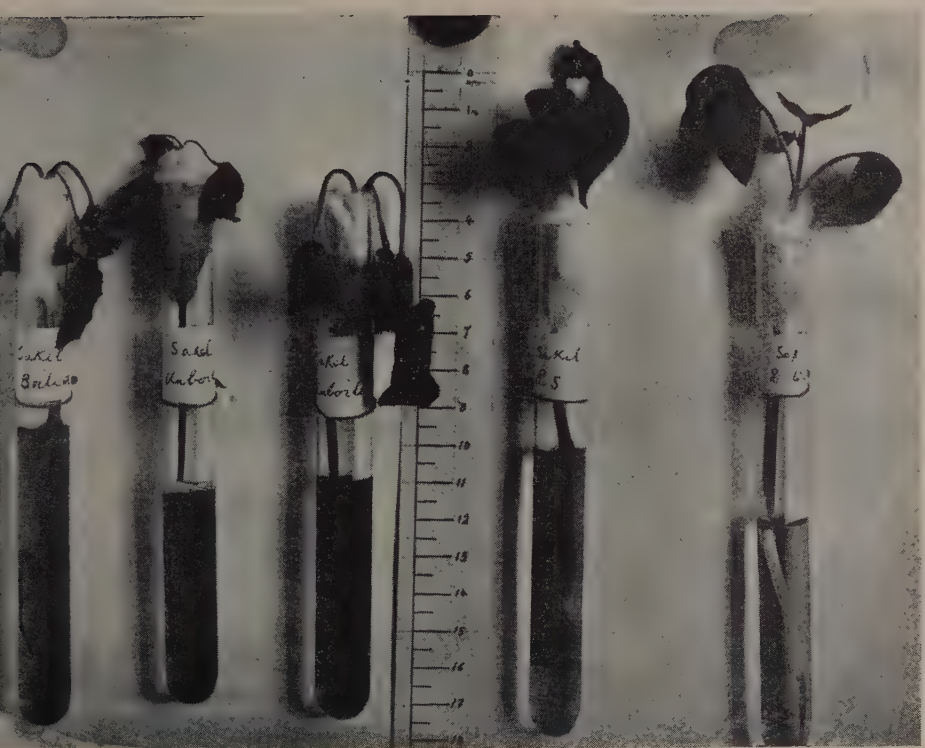
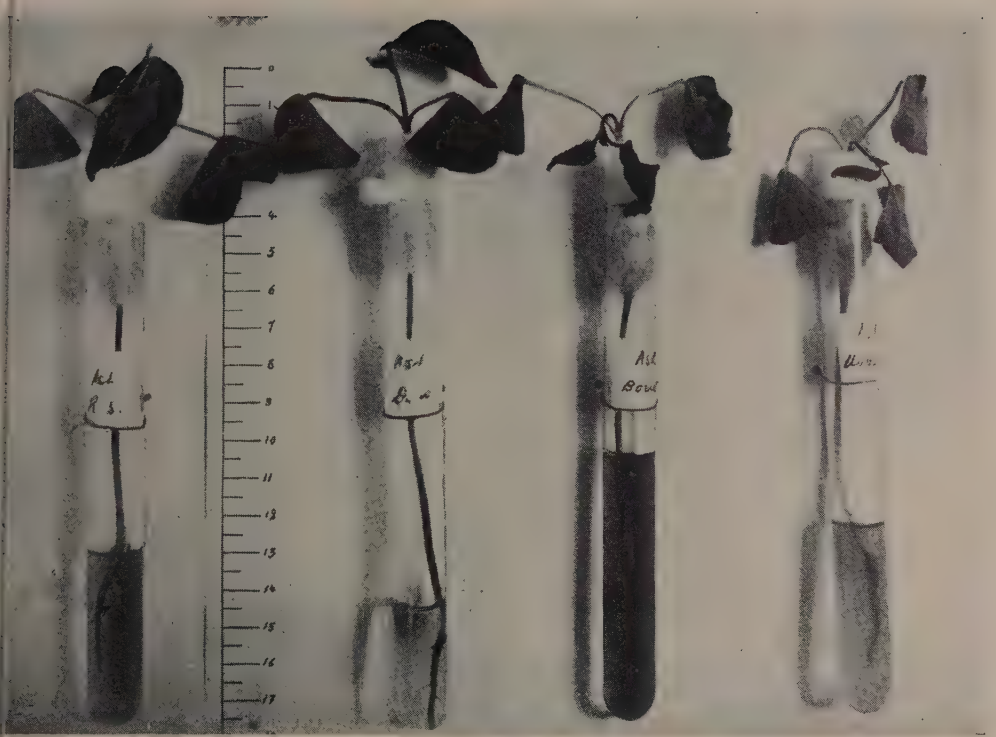


FIG. 20.—Two cultures of the Egyptian *Fusarium* parasite growing 1*a* on Butler's standard solution +3 per cent glucose; 2*a* on Butler's standard solution +3 per cent saccharose.



To the left: Sakel Cotton seedlings placed in the filtrate of a culture of the parasite (on Richard's solution), showing the wilting power of the filtrate.

To the right: Sakel Cotton seedlings, one placed in sterile Richard's solution, the other in distilled water. Note that the controls are normal.



22.—*To the right*: *Ashmûni* seedlings placed in the filtrate of a culture of the parasite (on Richard's solution), showing the wilting power of the filtrate.

To the left: *Ashmûni* seedlings, one placed in sterile Richard's solution, the other in distilled water. Note that the controls are normal.

FIG 23 — Part of stems of Resistant Cotton inoculated through wound, showing the limited discoloration at the point of inoculation. (Compare with Fig. 25.)

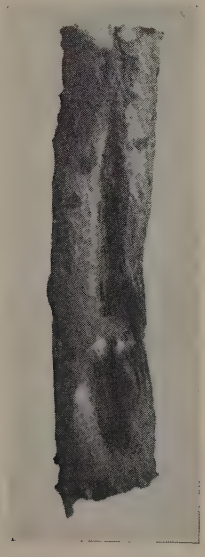


FIG. 24 — A portion of a stem of Sakel Cotton inoculated through a wound, showing a depression in the cortical layers where inoculation was made.

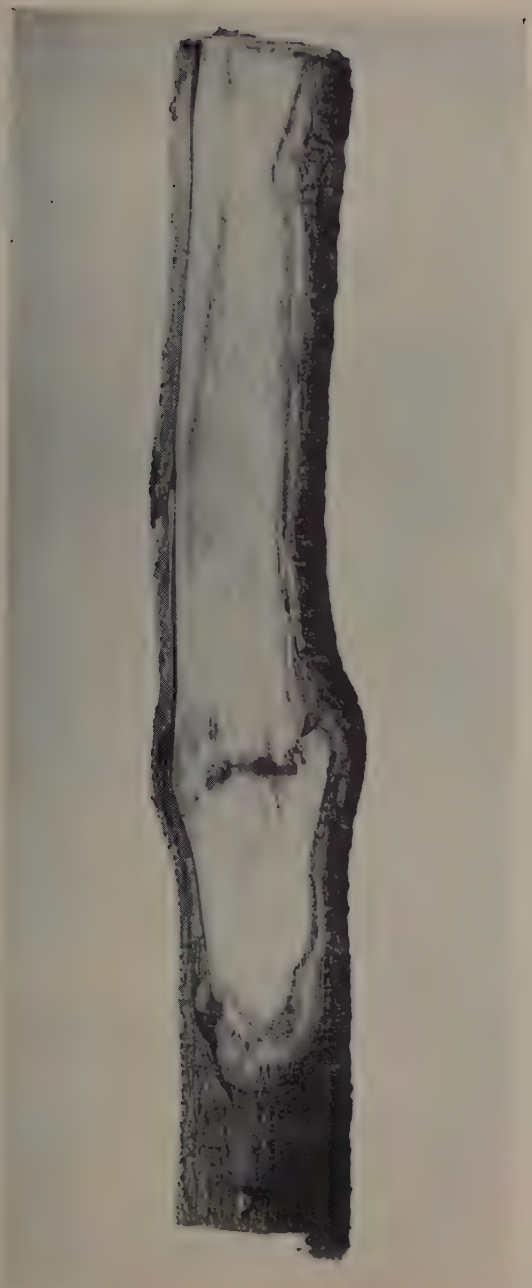


Fig. 25.—Part of the stem of a Sakel Cotton plant inoculated through a wound, showing a deeply discoloured localised portion from which characteristic discoloration is observed to extend in all sides.

Fig. 26.—Roots of Sakel Cotton.

To the left: Infected with Heterodera radicicola;
To the right: Healthy.

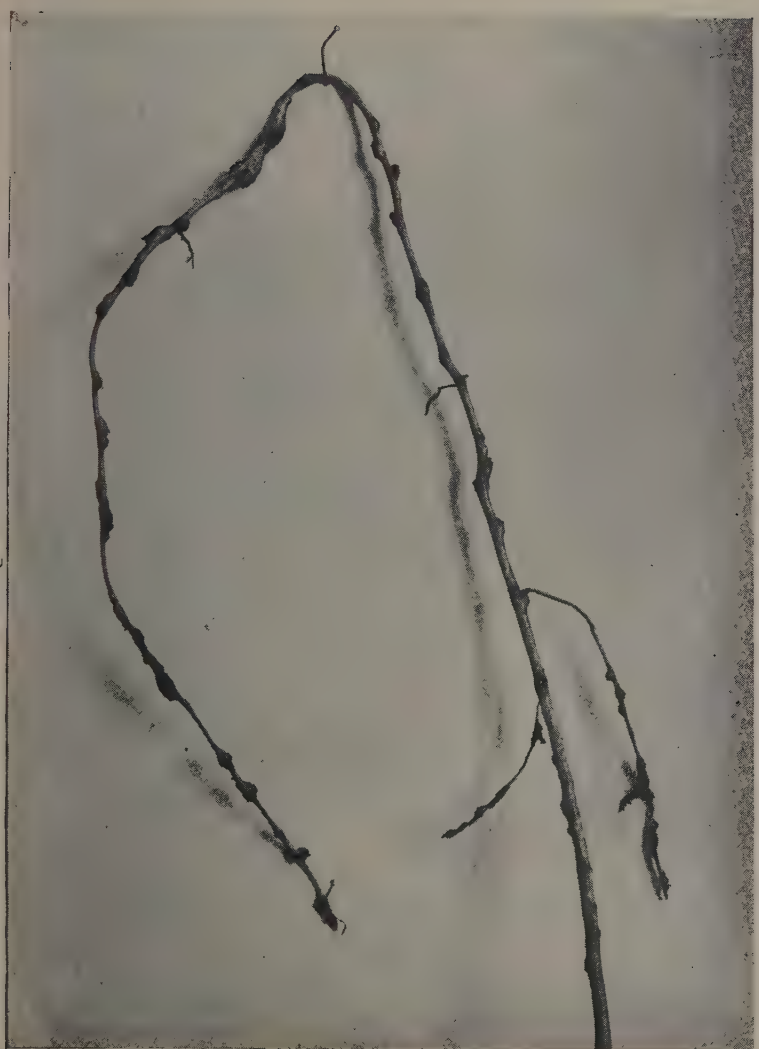


FIG. 27.—An enlarged photograph of part of Fig. 26, showing a part of a Sakel Cotton root infected with Heterodera radicicola.

Fig 28.—Slit roots of Sakel Cotton.
To the right: four plants showing characteristic discoloration.
In the centre: localised discoloration.
To the left: one healthy plant.

Rotation Experiment at Gemmeiza Farm.

FIG. 29.—A photograph of Plot 26 (one year rotation), showing the effect of repeated cotton growing as to the spread of the disease.

FIG. 30.—A photograph of a plot under the two years rotation, showing less damage than that shown in Fig. 29.

FIG. 31.—A photograph of a plot under the three years rotation, showing least damage.

FIG. 32.—A leaf of an Indian Cotton (G. Indicum) showing the mosaic-like symptoms as a consequence of infection by the Egyptian *Fusarium* of Cotton.

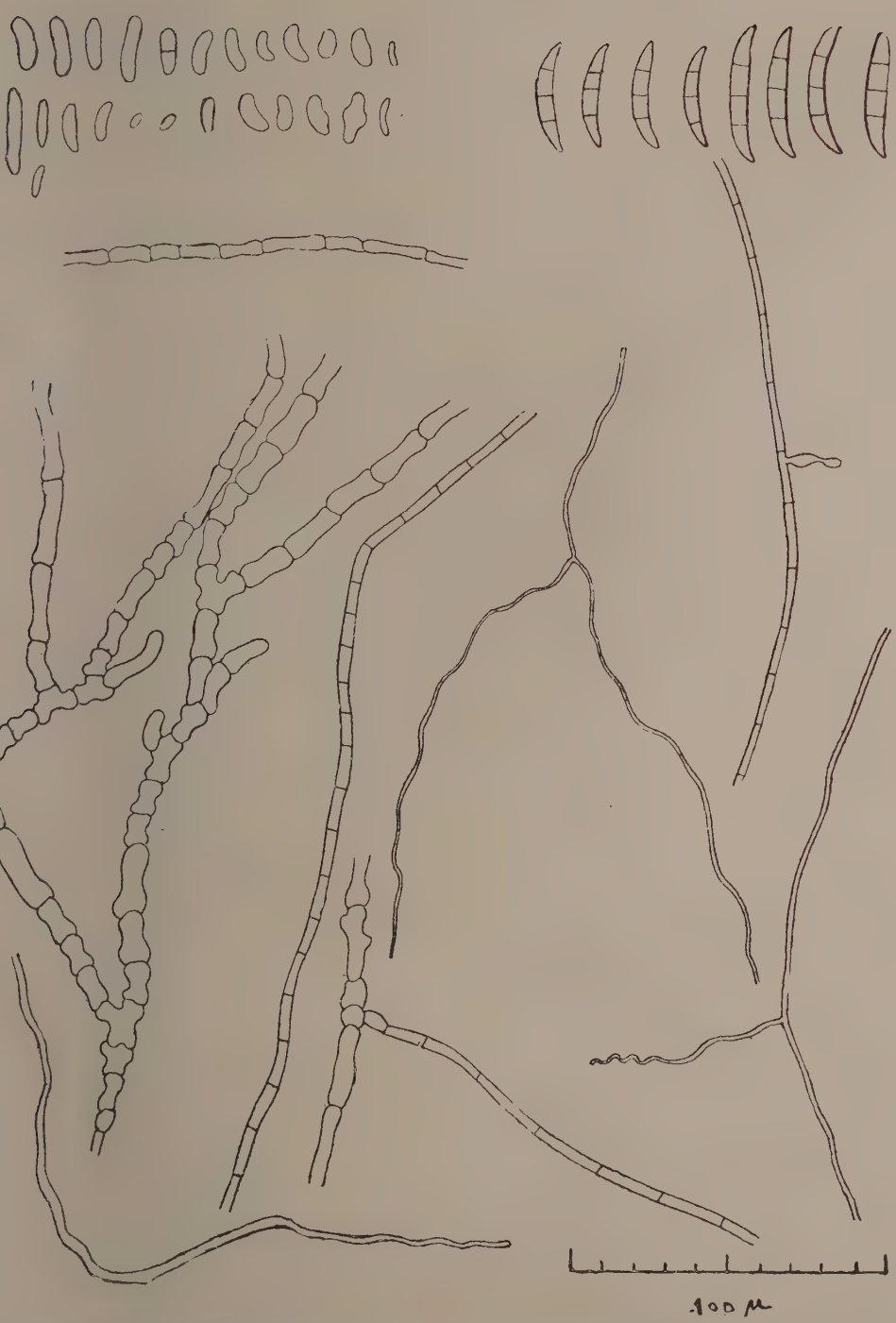


Fig. 33.—Some hyphæ Micro and Macroconidia of the Egyptian *Fusarium* of cotton, ×480.
(*M. Mamoun Abd el Salam* Delt.)

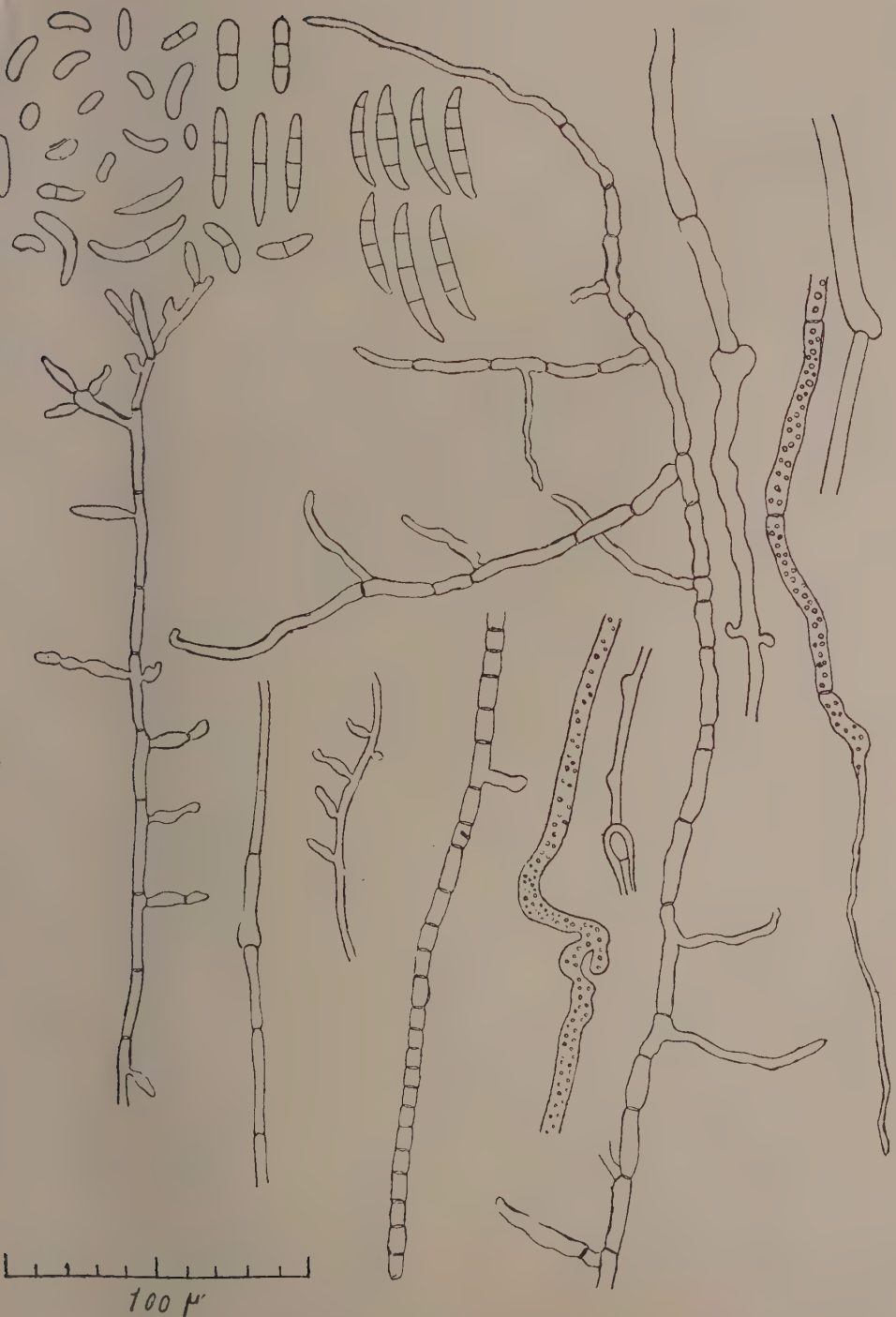


Fig. 34.—Some hyphæ Micro and Macroconidia of the Egyptian *Fusarium* of cotton, ×480.
(*M. Mamoun Abd el Salam* Delt.).

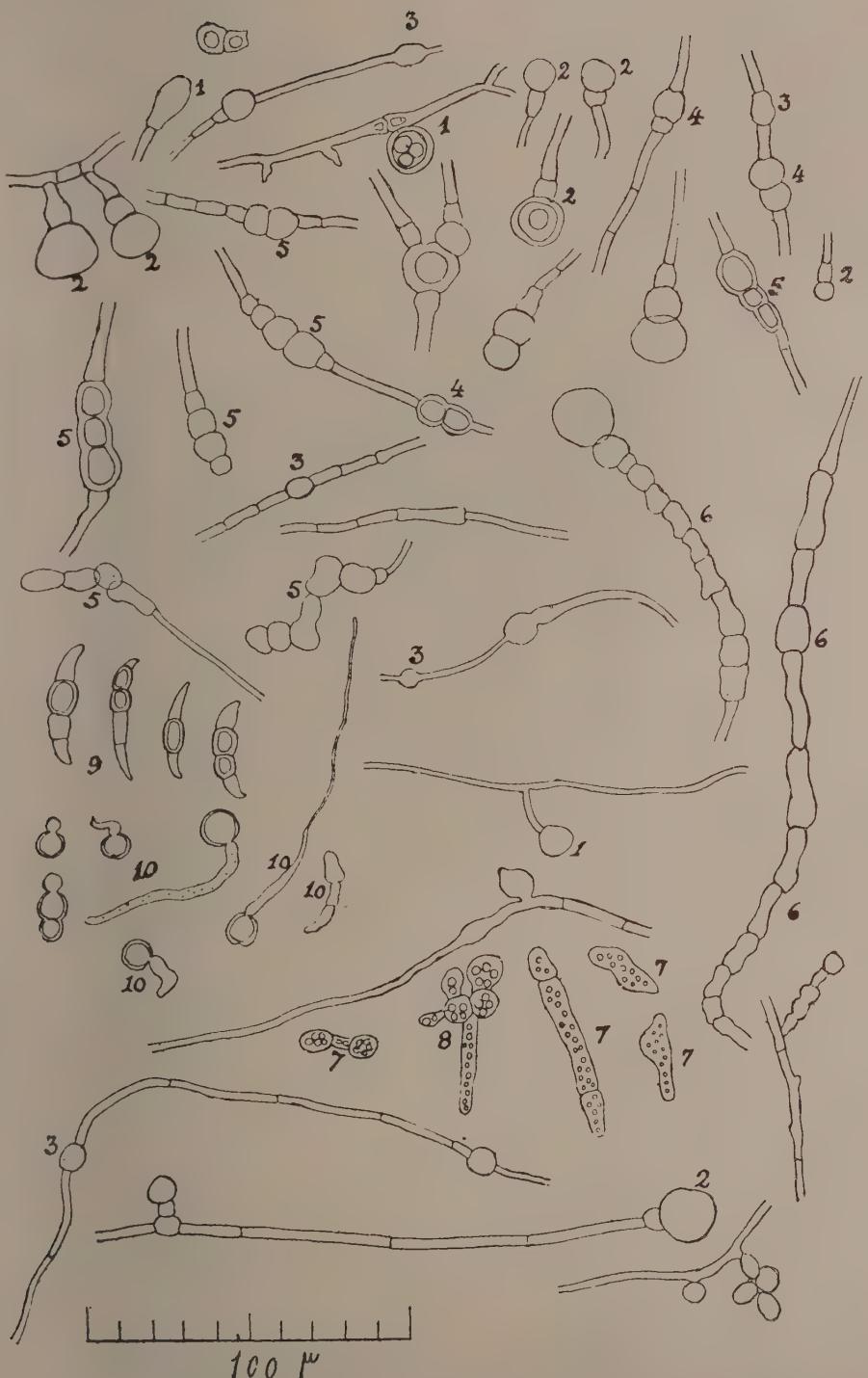


Fig. 35.—Different types of Chlamydospores of the Egyptian *Fusarium*, ×480.
(*M. Mamoun Abd el Salam* Delt.)

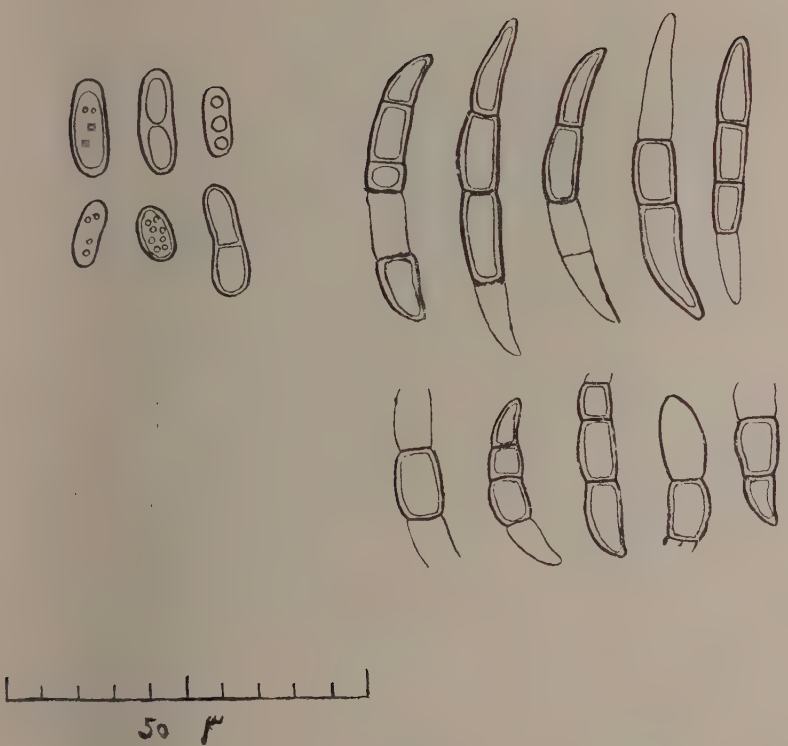


Fig. 36.—Micro and Macroconidia of the Egyptian *Fusarium*, showing the formation of conidial chlamydospores, × 1050.
(*M. Mamoun Abd el Salam* Delt.)

Fig. 38.—A potato particle showing the Egyptian *Fusarium* Fungus growing on it. ×1050.
(*M. Mamoun Abd el Salam* Delt.)

FIG. 38.—A potato particle showing the Egyptian *Fusarium* Fungus growing on it. ×1050.
(*M. Mamoun Abd el Salam* Delt.)

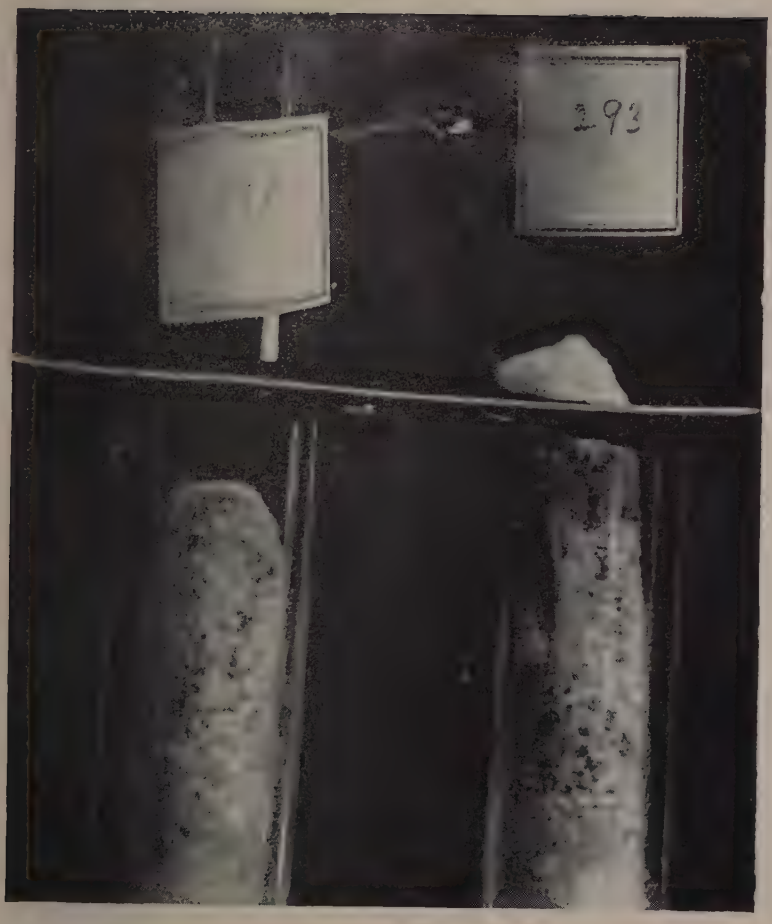


FIG. 39.—Two culture tubes of the Egyptian *Fusarium* on acid potato plug, showing the formation of groups of raised bodies.

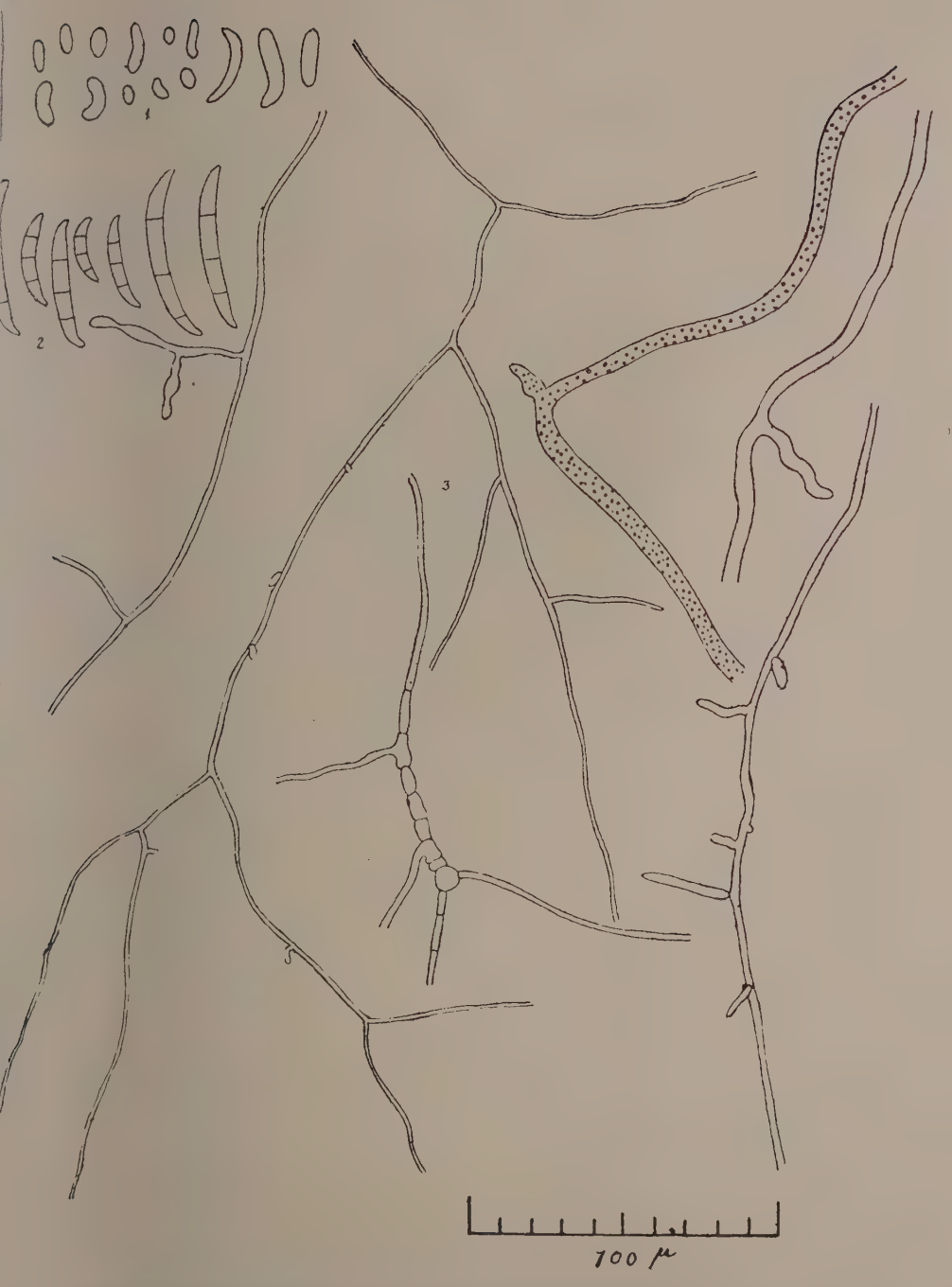


Fig. 40.—Some hyphæ Micro and Macroconidia of the Indian *Fusarium*. ×480.
(*M. Mamoun Abd el Salam* Delt.)

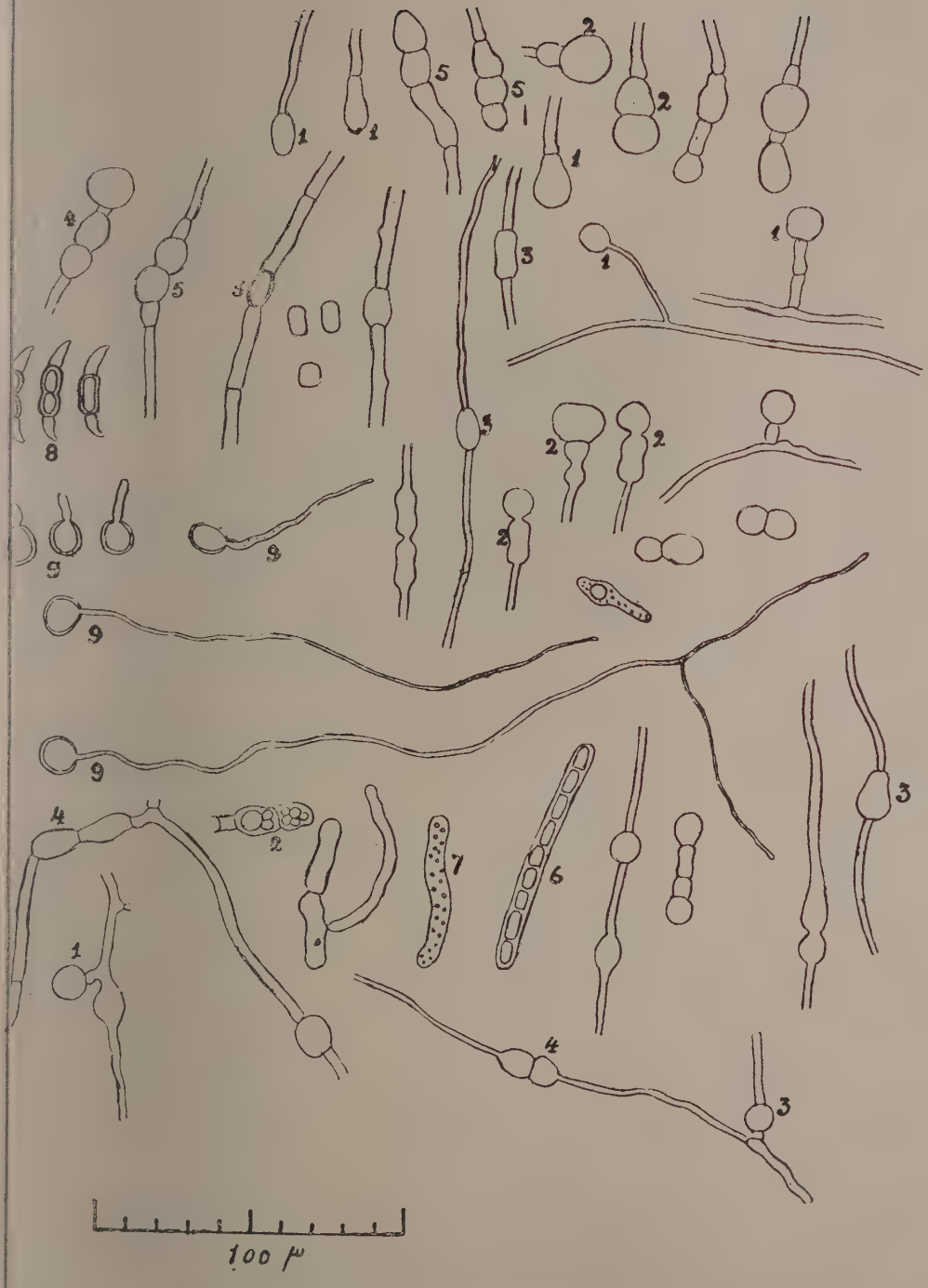


Fig. 41.—Different types of chlamydospores of the Indian *Fusarium*. × 480.
(*M. Mamoun Abd el Salam* Delt.)

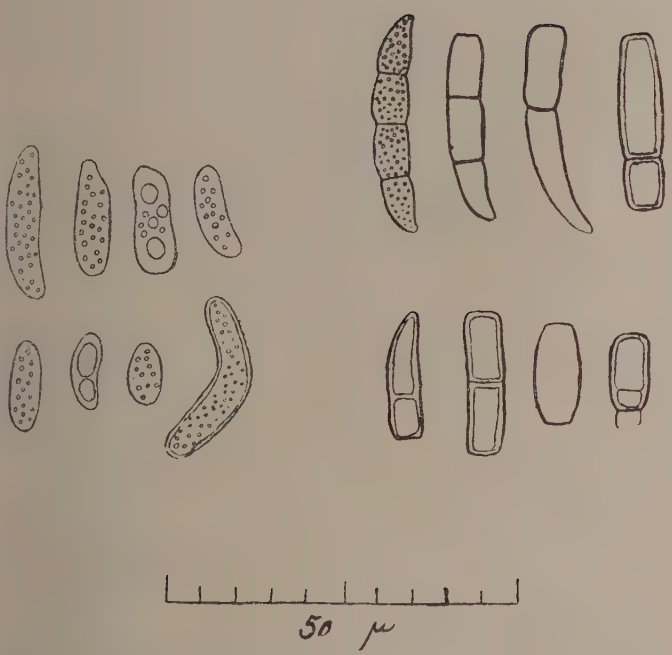


Fig. 42.—Micro and Macroconidia of the Indian *Fusarium*, showing the formation of conidial chlamydospores. × 1050.
(*M. Mamoun Abd el Salam* Delt.)

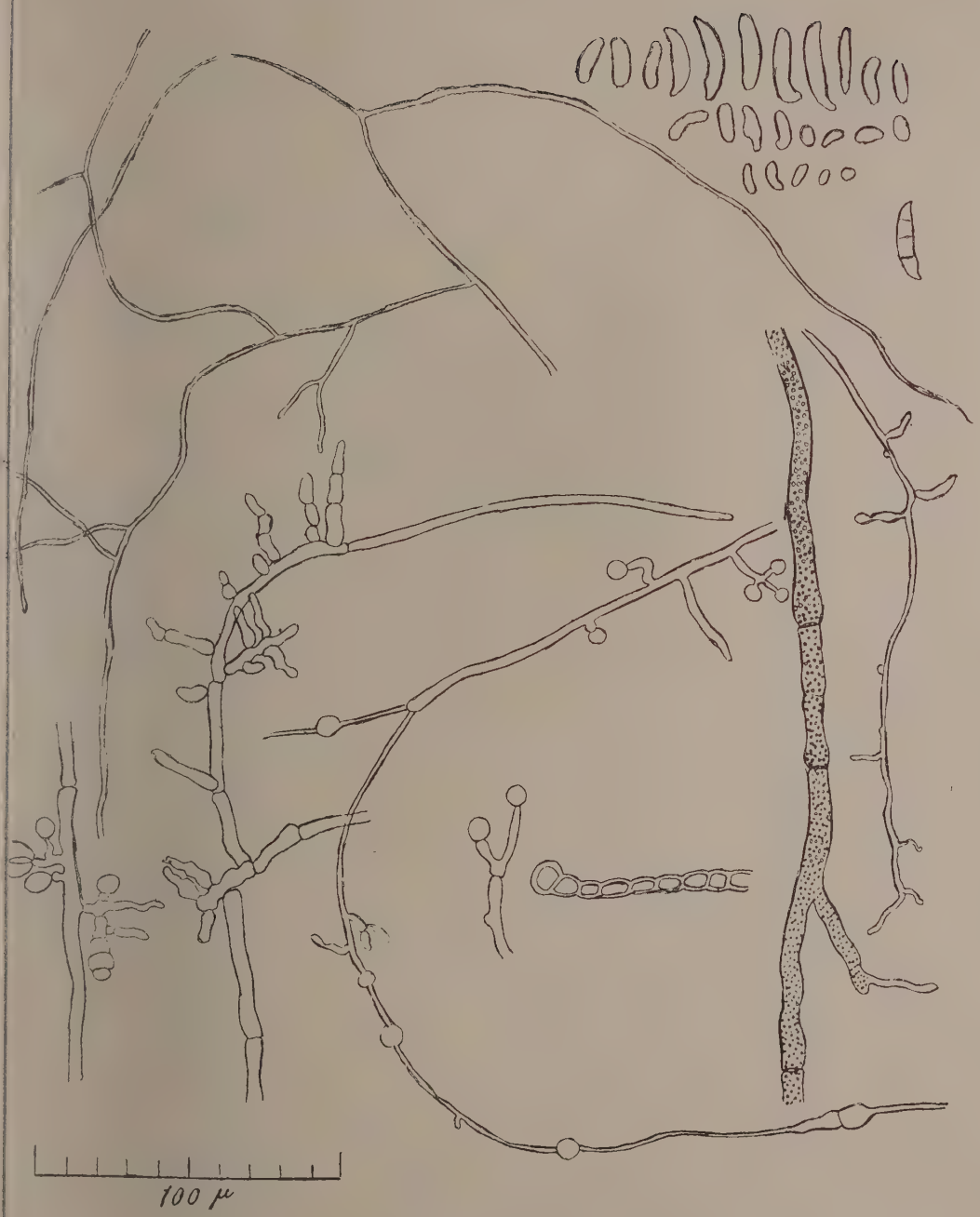


Fig. 43.—Some hyphæ Micro and Macroconidia of *Fusarium vasinfectum*. × 480.
(*M. Mamoun Abd el Salam* Delt.)

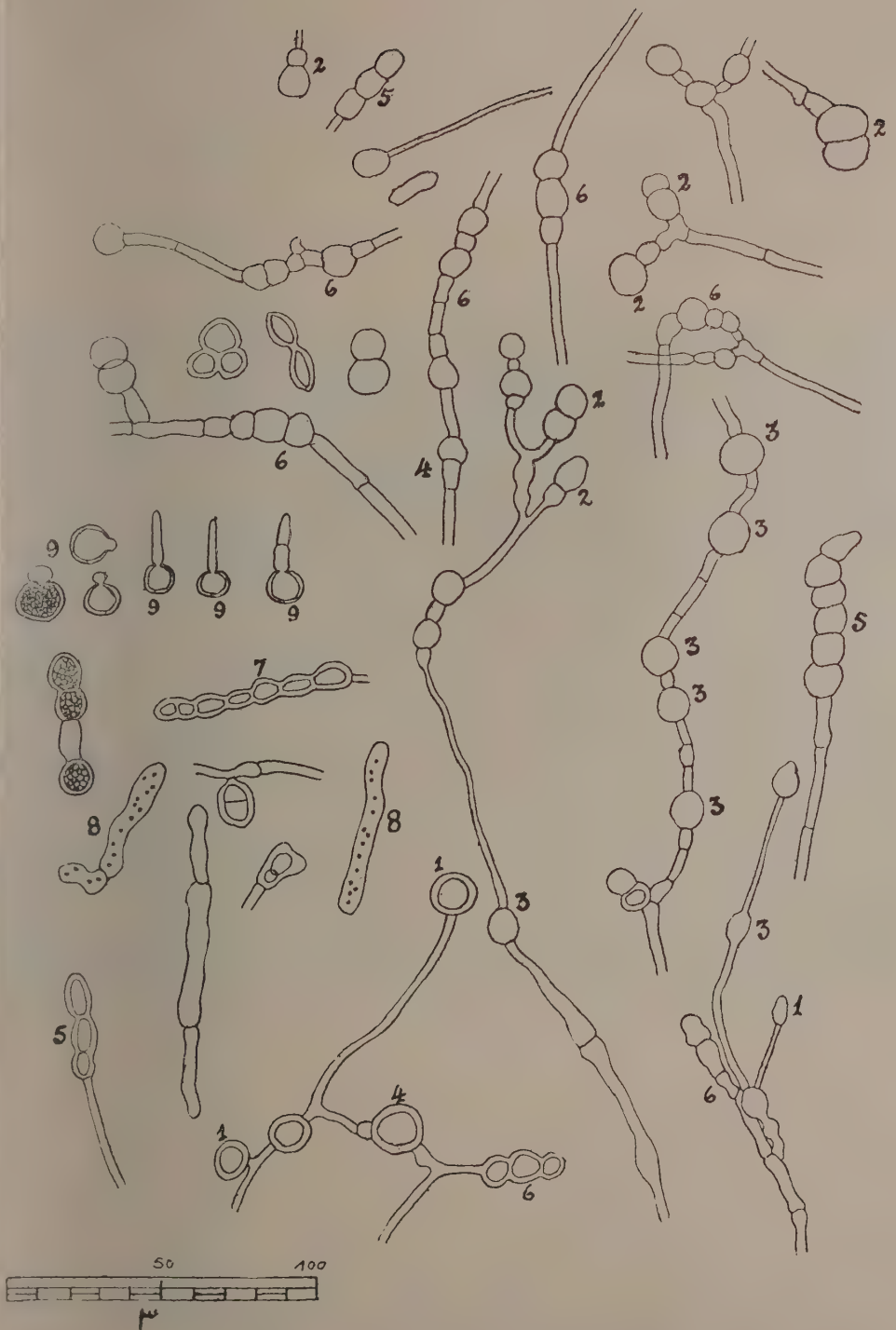


Fig. 44.—Different types of Chlamydospores of *Fusarium vasinfectum*. × 480.
(*M. Mamoun Abd el Salam* Delt.)

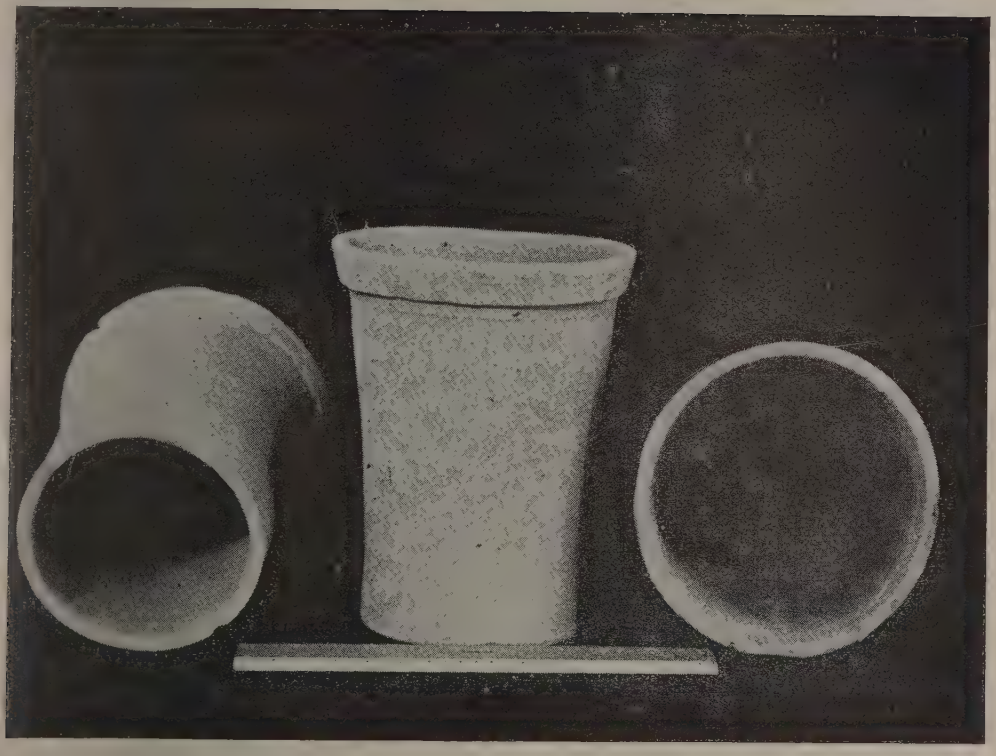


Fig. 45.—The Bottomless pots.

FIG. 46.—The Mycological Plot with bottomless pots placed in the soil.

FIG. 47.—The heaps of Gemmeiza soil infected with cultures of the Egyptian *Fusarium* isolated from the different province.

FIG. 48.—The selected resistant Sakel growing in bottomless pots.

FIG. 49.—Few plants of family 14/26 growing in bottomless pots.

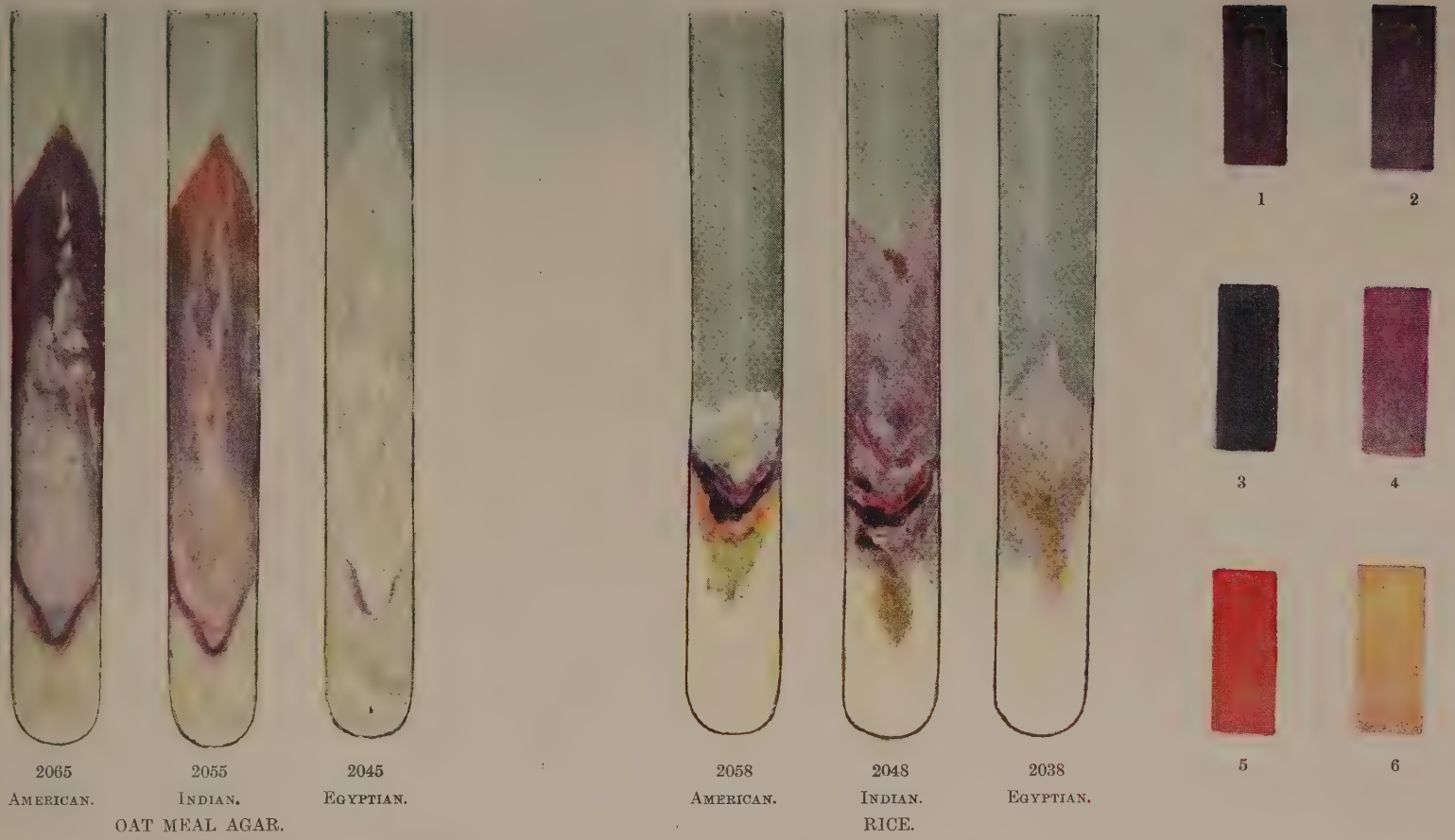


Fig. 50.—Substratum Colouration.

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